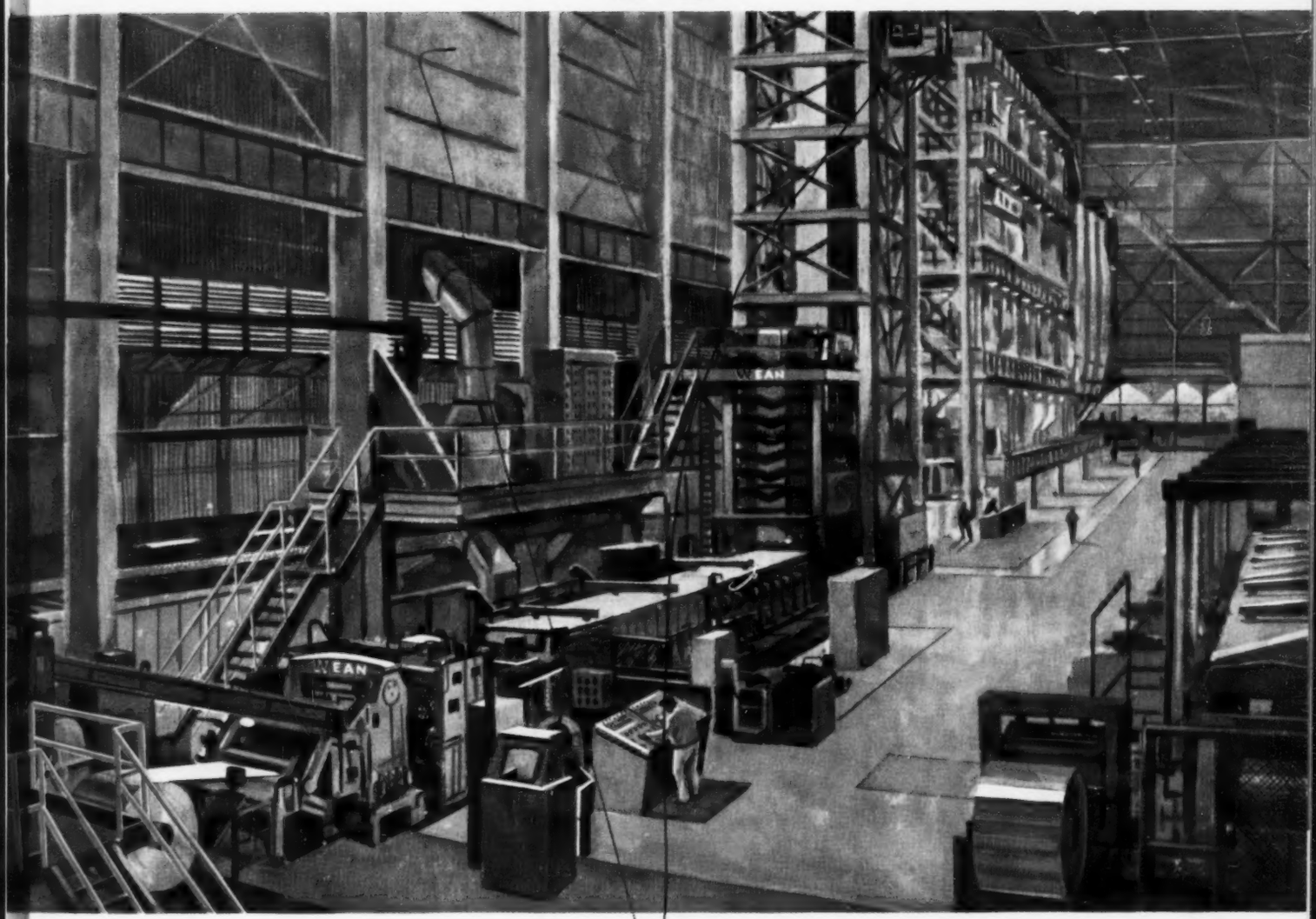
Iron and Steel ENGINEER

ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

MAY 1961



PORTRAIT OF PROGRESS: *Wean Tin Plate Annealing Line at J&L's Aliquippa Works*

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J&L Cuts Production Time, Improves Quality with Wean Tin Plate Annealing Line

Jones & Laughlin Steel Corporation's new Wean tin plate annealing line is a major part of the company's tin mill modernization at Aliquippa. Continuous annealing on the Wean line enables J&L to fill tin plate orders far more quickly than with the slower batch annealing process. And the Wean Line gives uniformly annealed strip for higher quality finished output.

Operating at speeds up to 2,000 fpm, the line can handle 50,000 lb. coils with a maximum O.D. of 85". Accurate *zoned* tension control is maintained by passing the strip through six electrically controlled precision bridles.

Whatever your requirements in sheet, strip or tin plate processing equipment, Wean's "creative engineering" stands ready to serve you.

THE WEAN ENGINEERING COMPANY, INC. · WARREN, OHIO

With *Alliance* it's a matter of principle!

PERSONALLY, I LIKE ALLIANCE CRANES... THEY HAVE THE PROPER DESIGN FOR OUR OPERATION.
TRUE, THEY KEEP MAINTENANCE COSTS AT A MINIMUM.
YOU FELLOWS ARE RIGHT! ALLIANCE'S MAXIMUM PRODUCTION GUARANTEES US THE GREATEST OVER-ALL RETURN ON OUR EQUIPMENT INVESTMENT.

From the Plant Superintendent...to the Plant Engineer...to the Maintenance Superintendent, ALLIANCE has continually earned the faith and respect of the industry.

In gaining this confidence throughout the world, the highest Principles of Guaranteed operation and performance are always the essential ingredients of ALLIANCE cranes.

ALLIANCE MACHINE COMPANY.... world's largest builders of the world's largest cranes.

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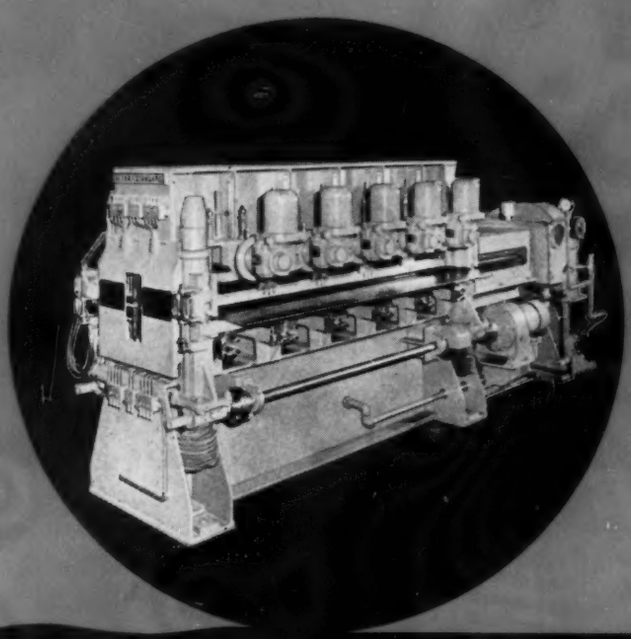
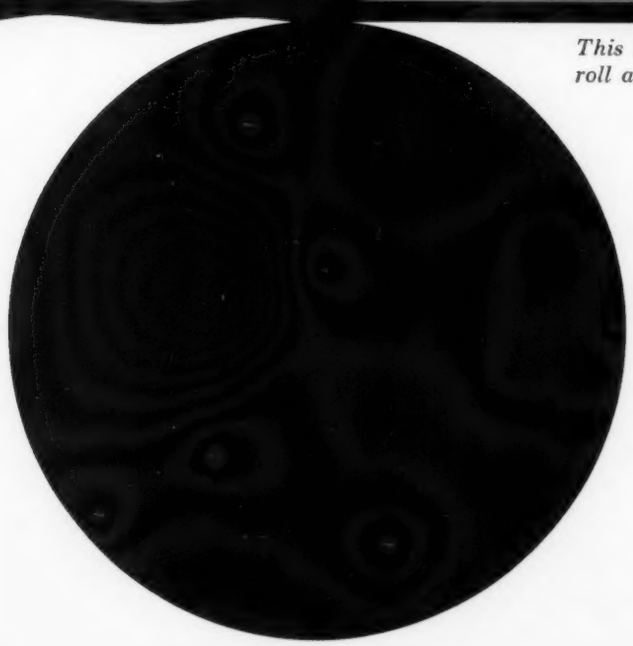




This Roller Leveler has individual motor-operated backup roll adjustments. 1¾" dia. x 72" face . . . 21 rolls.

BLAW-KNOX

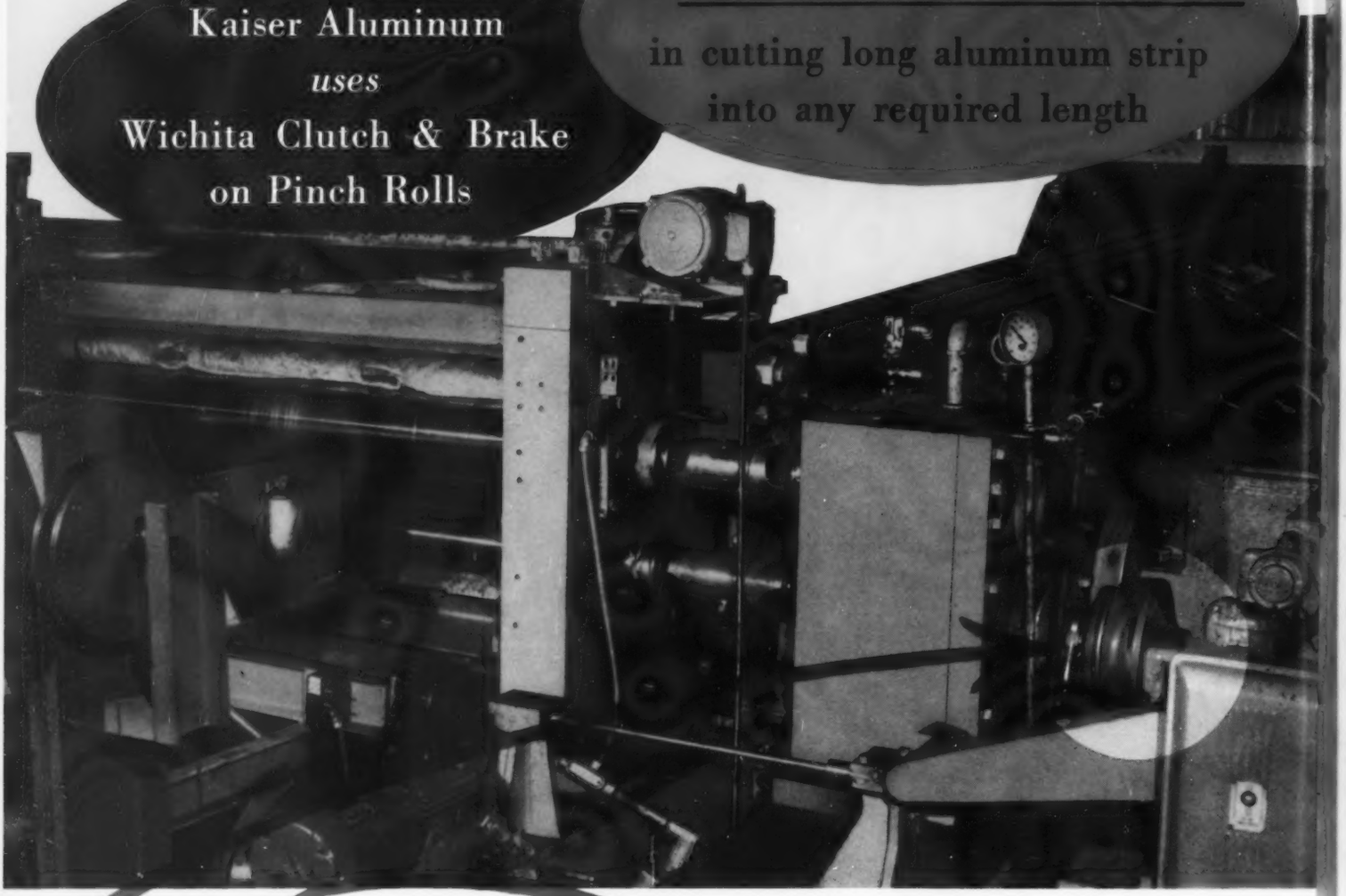
Aetna-Standard Division

BLAW-KNOX

Kaiser Aluminum *uses* Wichita Clutch & Brake on Pinch Rolls

...for added feed control

in cutting long aluminum strip into any required length



"Functioning very satisfactorily." . . . Kaiser Aluminum, in Spokane, found the addition of Wichita Clutch and Brake improved control on the pinch rolls feeding the shear.

The pinch rolls, top and bottom, feed a long aluminum strip into the shear. Due to the relative speeds between the pinch rolls and the shear blades, they can cut this long aluminum strip into any length required. The shear and pinch rolls are geared together. In order to have more control over minimizing the head end cut, the Wichita clutch was installed on the drive to the pinch rolls. This enables them to stop the pinch rolls with the strip inserted between rolls and to time the head end of the strip into the shear to minimize head end cut.

The tougher the clutching and braking problem is, the better Wichita engineers like it. That's because in many instances Wichita equipment gives outstanding performance under adverse operating conditions . . . and thus proves superiority more convincingly.

For difficult clutching and braking problems . . .

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This is McKay

McKAY DIE SHEAR LINES CUT MORE THAN STEEL. The most economical and efficient shear lines in operation today, they are being used by dozens of leading metal producers, fabricators and warehouses to slash shearing costs. Here, McKay Sales Manager Joseph F. Lyden, Jr., and M. G. Slaney, Building Division Manager, The Parkersburg (W. Va.) Rig and Reel Company — one of the nation's fastest growing manufacturers of pre-engineered metal buildings — examine panel sections cut to length by the high speed McKay Die Shear Line in the background.

Photo by Arnold Newman

Machine....

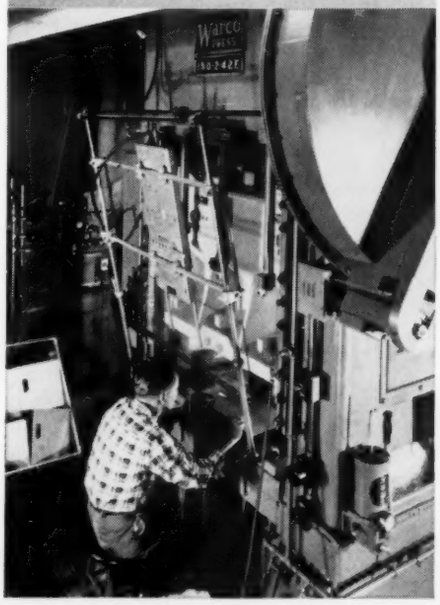
a recognized leader in the development and manufacture of high production metal processing equipment!

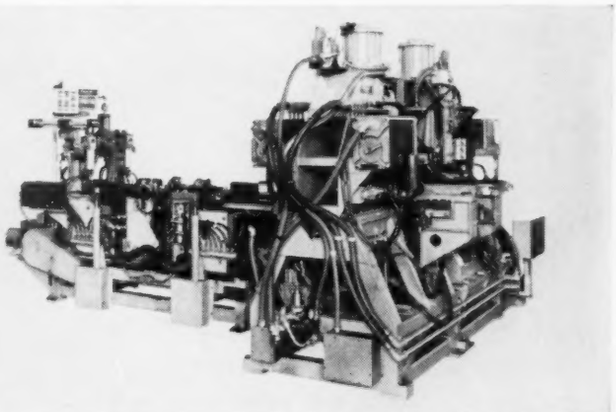
If you fabricate metals and are caught in the "profit squeeze" you'll want to know more about McKay Machine.

It was McKay Machine that pioneered automated integrated production lines, and it is McKay Machine that is today a leader in this field. We have conceived and produced complete lines for the manufacture of building panels, aircraft and missile sections, appliances, cabinets and components, automotive bodies and parts, and farm equipment—lines that are completely automated from *raw material to finished part or product.*

Whatever you make, if it requires metal handling, feeding, slitting, shearing, stamping, welding or forming, it's just good business to acquaint yourself with *McKay Packaged Production Lines*—high speed production equipment engineered to work in unison—with one-source responsibility from start to finish. Write for literature to *The McKay Machine Company, Youngstown 1, Ohio.*

WARCO MECHANICAL PRESSES—advanced in design, noted for their craftsmanship — are used throughout industry. Typical is the high speed, low maintenance 150-ton straight side crank press pictured here in operation at Eastman Kodak.

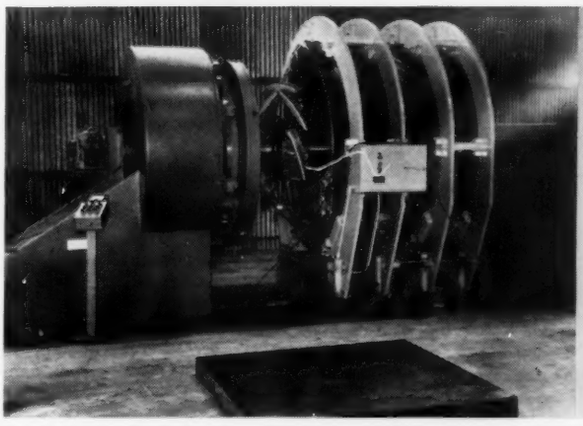




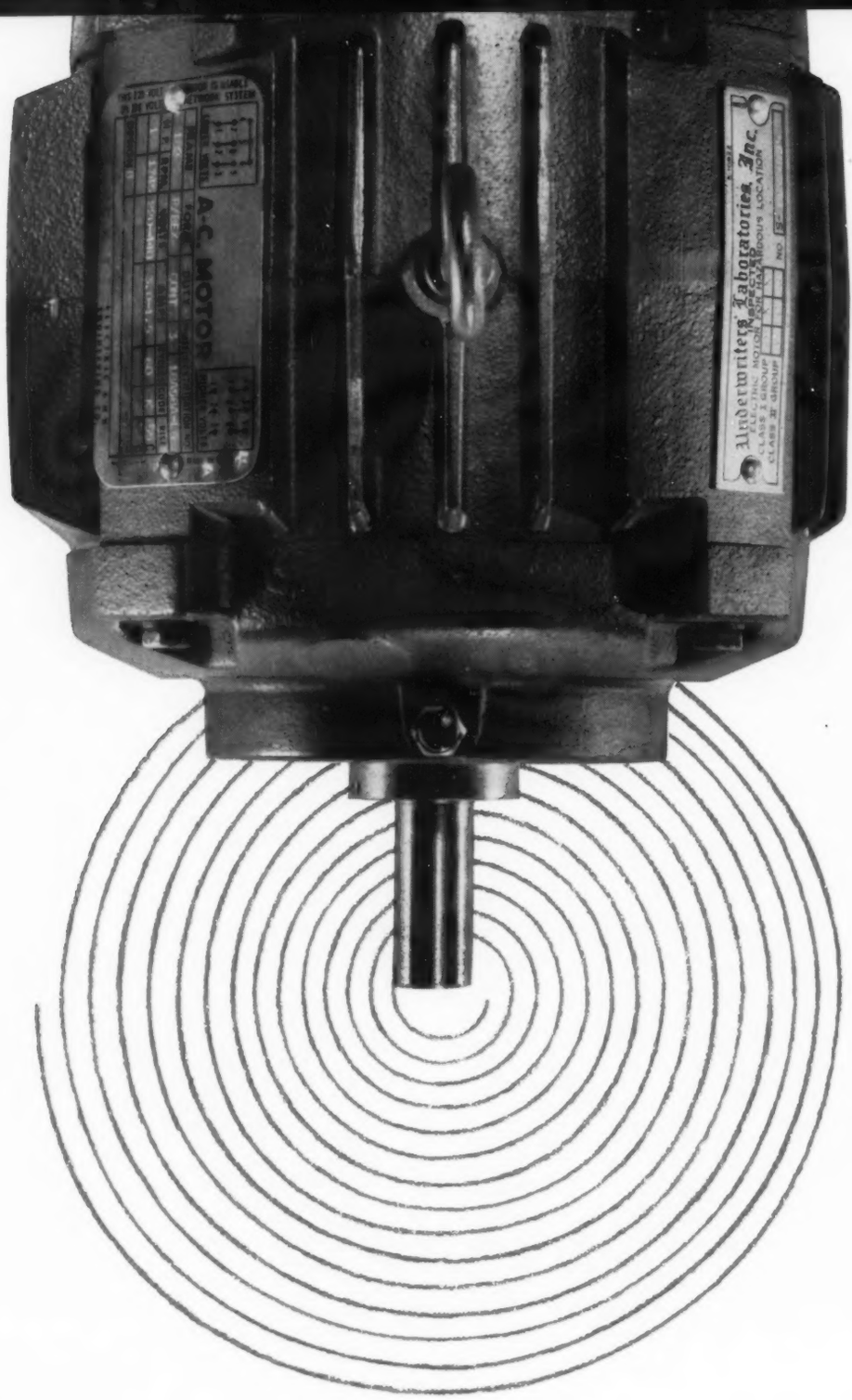
FEDERAL RESISTANCE WELDERS AND WELDING LINES, like this multi-gun combination spot and projection welder used by Hotpoint on their range production line, can be found in the plants of leading metalworking firms the nation over. Individual units, or complete resistance welding lines, are engineered to specifications by McKay's Federal-Warco Division.

LOOK TO

McKAY MACHINE



BERKELEY-DAVIS AUTOMATIC ARC WELDING MACHINERY produced by Berkeley-Davis, Inc., a subsidiary, is highly popular in the aircraft, rocket, automotive and appliance industries. The rocket body welder pictured here is working at Aerojet General, subsidiary of General Tire and Rubber Company.



OPEN UP: for better electrical steels

The Open Coil Process of Gas Alloying permits the control of carbon after the steel has been rolled. Carbon can be removed during the annealing operation. This means that silicon steels of better magnetic properties can be easily and economically produced. By removing carbon from plain carbon steel it becomes an excellent replacement for low silicon grades in many applications. To get all the details on this revolutionary new Open Coil Process of Gas Alloying write for Bulletin OC-960 to *Lee Wilson Engineering Co., Inc., 20005 Lake Rd., Cleveland 16, Ohio.*

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Originators and Leading Producers of Open Coil and Single Stack Furnaces

DAVY-UNITED

AUTOMATIC GAUGE CONTROL

OPERATING IN CANADA

56-inch 4-High Cold Reversing Mill at Dominion Foundries and Steel Limited, Hamilton, Ontario, which is equipped with the Davy-United system of Automatic Gauge Control. This mill rolls steel strip for tin plate between 24 inches and 50 inches wide in a range of thicknesses from .006 inches to .050 inches.

Six Automatic Gauge Control installations have now been completed or ordered in North America and Licensees in North America for the Davy-United system of Automatic Gauge Control include General Electric Company of the U.S.A., Canadian General Electric Company Limited and Canadian Westinghouse Limited.

DAVY-UNITED | DAVY-ASHMORE GROUP

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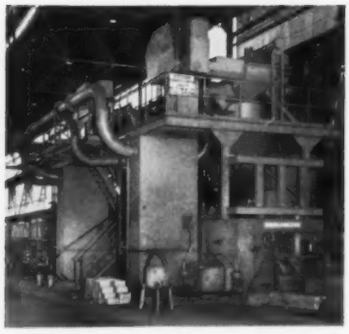
379/DV

What are the vital savings you want in descaling of strip, sheets, plate, wire rod, structural shapes, slabs or billets? If it's space savings, a Wheelabrator Mechanical Descaler will replace hundreds of feet of pickling tanks. If it's acid elimination, pickling with its attendant problems can be eliminated or radically reduced. If it's savings in metal, Wheelabrator descaling removes scale only. There's no metal loss. If it's cost reductions, a better finish, improved drawing, less handling or more rapid visual inspection, Wheelabrator can give you these savings. Wheelabrator gives you all this plus the Vital Value of experience—of being the initiator of blast descaling, of participating in more installations than any other firm. Ask for "Pictorial Report" Bulletin 156-D.

A demonstration of WHEELABRATOR'S

VITAL VALUES

8 vital savings in steel descaling



15,500 tons of carbon steel strip a month is Wheelabrator descaled in the modern mill of Altos-Hornos De Mexico SA. Steel is descaled at (up to) 200 f.p.m. contrasted to only 100 f.p.m. by previous pickling method.

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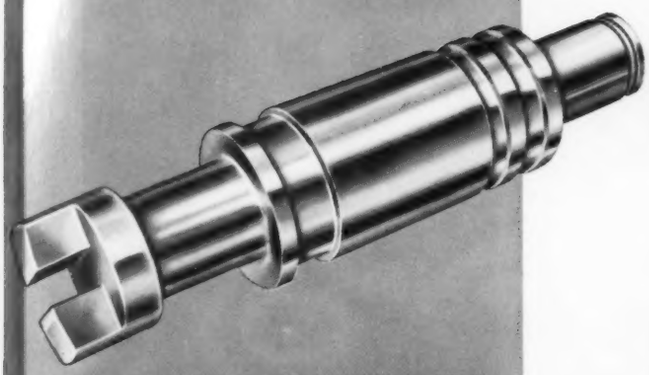

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△ About 625 men registered for the AISE 1961 Spring Conference, April 24, 25, 26, at the Sheraton-Jefferson Hotel in St. Louis. It was the first AISE national meeting in St. Louis since 1919. Attendance at the technical sessions was good and the papers presented there received many fine comments. W. M. Akin, president of Laclede Steel Co., spoke to the dinner crowd, presenting a very interesting outline of the history of iron and steel in the St. Louis area. About 200 men made the inspection trip to Granite City Steel Co.

AISE extends sincere thanks to all who helped to make the meeting a success.

△ Addressing a labor and industrial relations gathering at East Lansing, Mich., R. Conrad Cooper, executive vice president—personnel services of United States Steel Corp., said: "The enforcement of uniform wage and benefit increases upon the many competing companies obviously poses unequal problems for the individual companies and plants. The ultimate result of such a practice, if continued, can only be the destruction of jobs and employment in companies unable to remain competitive."

"The over-all consequence of this union power in the steel industry from 1940 through 1958 was an average rise in total employment cost per man-hour of about 8 per cent per year compounded. During this same period of time, total costs per man-hour rose at about the same rate, but the investment of tremendous sums of money and all other actions to improve productive efficiencies produced an average increase in steel shipments per man-hour of only 2 per cent per year compounded."

△ The Wall Street Journal defines a moonlighter as a man who holds day and night jobs so he can drive from one to the other in a better car.

△ India's third five-year plan, just starting, will increase the capacity of the country's three principal government-owned plants. Bhilai will be expanded to an annual capacity of 2,500,000 tons, with the foreign exchange portion of the cost financed by Russian credit. Rourkela will increase to 1,800,000 tons per year, aided by West German credit. Durgapur will be stepped up to 1,600,000 tons per year with credit from United Kingdom sources. A fourth plant is under consideration, to be built at Bokaro with an annual capacity of almost 1,000,000 tons.

△ As a result of a survey of visiting salesmen, the purchasing department of A. O. Smith Corp. concluded that 31 per cent rely on influence or pressure, 28 per cent resort to reciprocity and 14 per cent try to "buy you" with a lunch. More than 40 per cent don't know their product.

△ Automatic dishwashers are popular because most husbands would rather buy than be one.

△ According to the American Iron and Steel Institute, the iron and steel industry had a record number of stockholders—1,122,833—in 1960. It is the seventh year in which stockholders outnumber the employees of the reporting companies.

Wonder if the politicians know this!

△ South African Iron & Steel Industrial Corp. has started production in its new rotor steel plant in Pretoria. This is the company's second plant of this type, the unit at Vanderbijlpark having been in production for some time.

△ This is the time that many men take up gardening—and most of them will only grow tired.

△ American steel producers are taking another look at steel imports and foreign competition. Some time ago, *The Blast*, published by Colorado Fuel and Iron Co., carried an analysis by A. F. Franz, C.F.&I. president, headed "Imports Are Exporting Your Jobs." Mr. Franz made the point that, although exports might balance imports overall, producers of certain kinds of steel products were hit hard because imports are principally in their field. More recently, *Inland News*, a quarterly put out by Inland Steel Co., devoted its entire spring issue to foreign industry and commerce. In it, Philip D. Block, Jr., emphasized the need for making our products more competitive with foreign merchandise and building up a larger foreign market, which in turn demand the development of new technologies and the holding of costs and prices to competitive levels.

△ President Kennedy's much publicized rocker leads to an obvious question: "Is he on or off?"

△ Although first quarter reports from the steel companies are not particularly good, orders for steel have stepped up operations enough to present an encouraging outlook. Steel company officials are unanimous in predicting profitable operations for the second quarter.

△ A correspondent asks us if it's really true that editors call themselves "we" so a person who does not like the article will think there are too many to lick.

△ Accidents killed 38,000 persons and injured 3,078,000 on U. S. highways during 1960. Excessive speed is the principal offender. Drivers between the ages of 18 and 25 are involved in twice the number of accidents their numbers would warrant. The safety record of commercial vehicles is far better than that of the private passenger car.

Wayne County Drain Commission, Wyandotte Pumping Station, recently equipped with two new Fairbanks-Morse pumps and motors

Consulting Engineers • Hubbell, Roth & Clark, Inc., Birmingham, Mich.
Electrical Contractor • Fife-Pearce Electric Co., Detroit, Mich.

Certificate on File in Cleveland

Certified Fault Protection WITHOUT FUSES!

EC&M Fuseless Starters

ELIMINATE FUSE PROBLEMS & COSTS

Now you can get full fault protection without the problems associated with fuses. EC&M's fuseless starters have certified interrupting capacities of 100,000 KVA at 2400 volts, 150,000 KVA at 4800 volts — an important consideration when starters were selected for the 1250-hp, 4800-volt starters at Wyandotte Pumping Station. This inherent fault protection is an EC&M "exclusive" — and is available with no first-cost premium.

EC&M starters are safe and easy to maintain. A three-way door interlock gives positive personnel protection, and an interlock is provided between the contactor and disconnect switch. Disconnect blades are visible in the open position when the door is open. No roll-out or draw-out needed for maintenance. All six contacts can be replaced without special tools in 10 minutes or so.

These cost-saving features make EC&M starters the logical choice for 2200-4800 volt motor drives.

TYPICAL SAVINGS WITH EC&M STARTERS

	Fused Starter	EC&M Fuseless Starter
Cost of 1250-hp 4800-volt Starter	$xxx.xx	Same as Fused Starter
Spare Fuse Costs: Set of 3 Spare Fuses for 1250 hp	$470.00	0

***SAVE** per starter, up to $500*
(more on larger motors)
...with EC&M Fuseless Starters

Write **FOR DETAILS • Ask for Bulletin 8130**
Square D Company, EC&M Division, 4500 Lee Road, Cleveland 28, Ohio

SQUARE D COMPANY
EC&M DIVISION • CLEVELAND 28, OHIO
wherever electricity is distributed and controlled

6520

"Electric arc melting gives us improved metallurgical quality at an economic advantage," says Birdsboro Corporation.

Steel castings provide a wide range of selective materials, both as to chemical analysis and mechanical properties, which are suitable for application in various service and environmental conditions. The recent selection by Birdsboro Corporation of two new electric arc furnaces to replace open hearths and to complement existing arc melting facilities has contributed markedly to diversification of their steel foundry operations to meet these requirements.

Demand has been matched with flexible melting capacity through installation of two Heroult Electric Arc Melting Furnaces:

Shell Size	Capacity	Melting Rate
8-foot	10-ton	2 tons per hour
13.5-foot	30-ton	7 tons per hour

These two furnaces increase total electric melting capacity to 300 tons per day.

Service to customers was the primary requisite in Birdsboro's selection of this equipment. In addition, sales possibilities have increased, quality of metal is superior, alloy recovery is higher, maintenance is reduced, and man-hours per ton is lower. Result—steady improvement of steel melting costs.

American Bridge constructs furnaces for all types of arc melting, in charge capacities to over 200 tons. You can select door-charge or swing roof top-charge types. Your crew can easily maintain a Heroult furnace.

If you're after melting flexibility, increased production, and lower costs, check American Bridge's complete design, construction and installation service.

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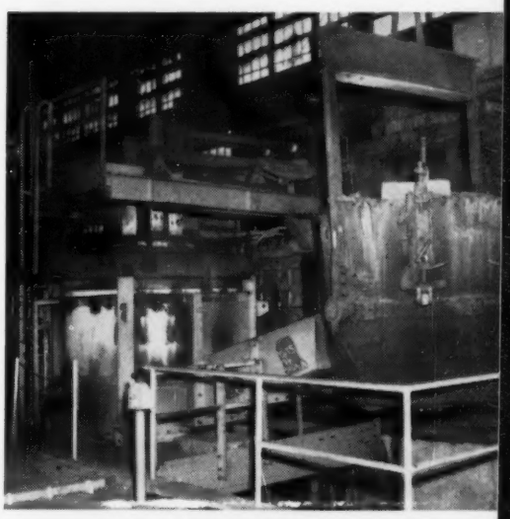
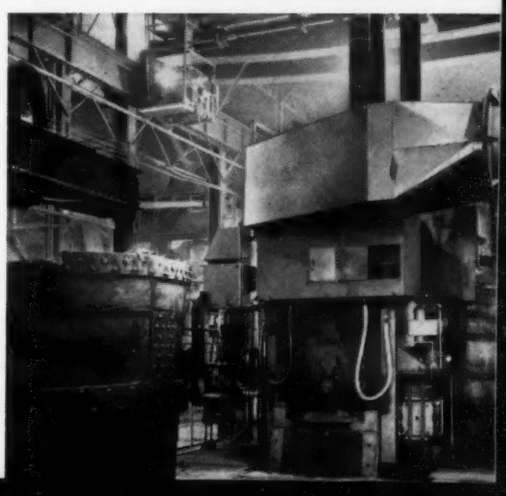
This mark tells you a product is made of modern, dependable Steel.





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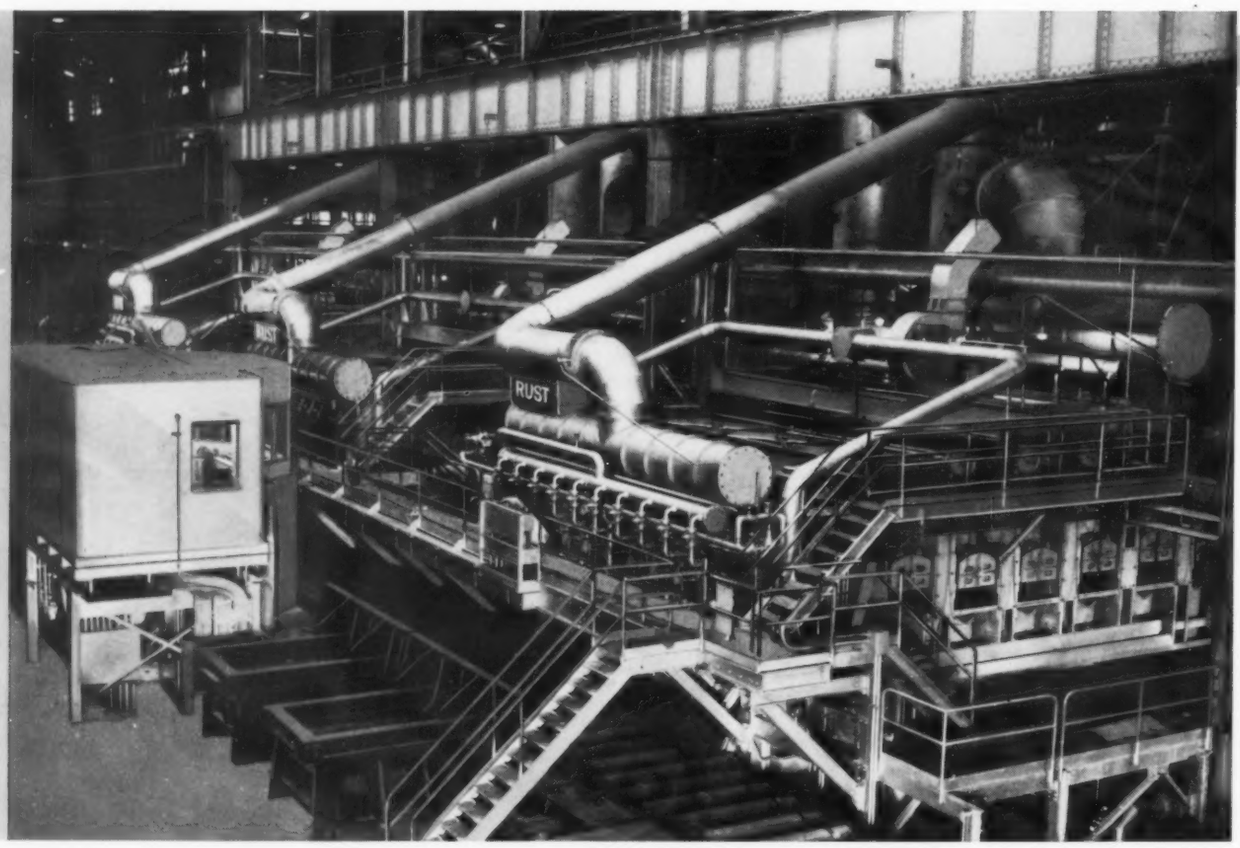
ELPIT® electric soaking pits

RUST

Pioneers in Furnace Design

Rust Furnace Company



five-zone slab furnaces

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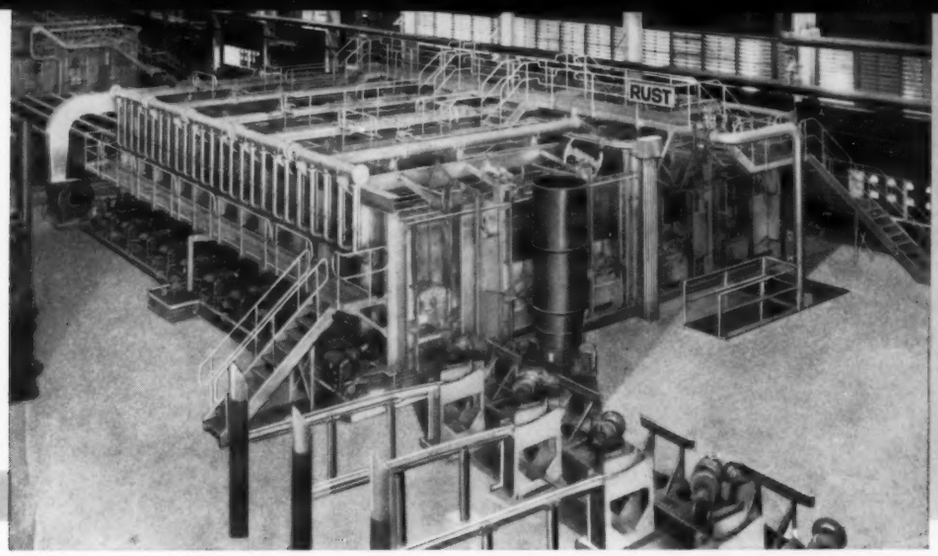

walking beam reheating furnaces

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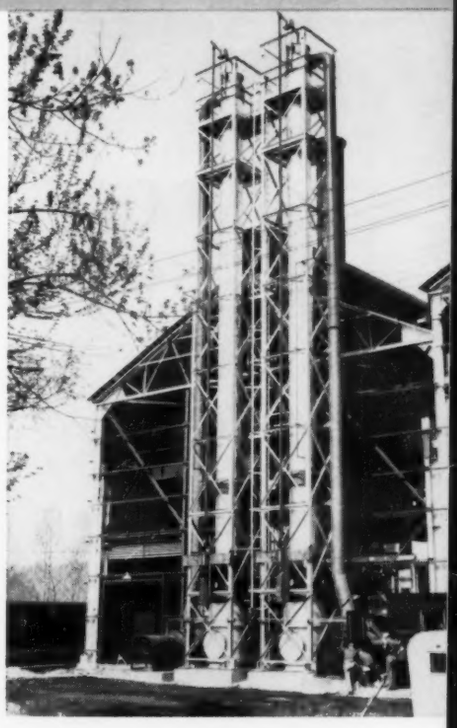
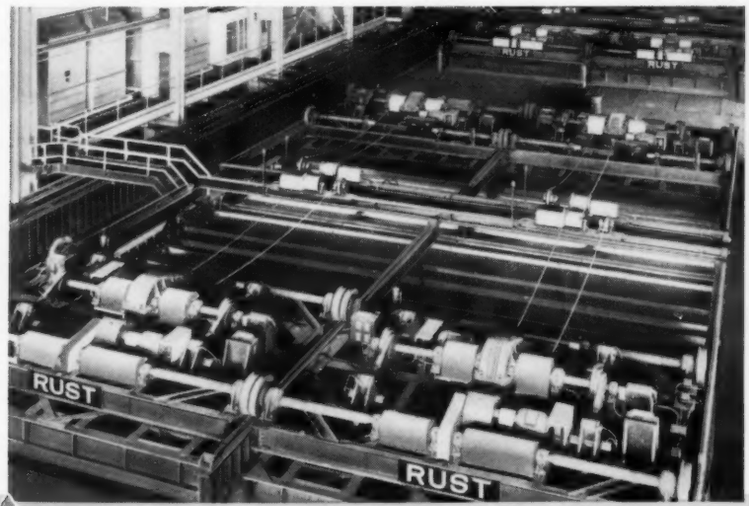
Over 800 contracts completed, representing over 1000 heavy industrial furnaces throughout the world.



Rust-Escher recuperators



regenerative soaking pits

RUST FURNACE COMPANY

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Wagner® Silicone Rubber Insulated Motors

Power-packed drip-proof polyphase motors that are exceptionally moisture-resistant . . . save you money in lower initial equipment cost for many applications

These are motors that are built to take on and tame the toughest jobs. Big, job-rated motors, available in frames larger than 445U, through 1000 horsepower. Perfect drives that can be used for station auxiliaries, in chemical plants, in rubber and paper mills and in the petroleum industry.

With motor coils completely sealed in a jacket of silicone rubber and housed in a compact, drip-proof enclosure, these Wagner® motors are suitable for use in highly humid atmospheres. They perform perfectly even after long exposure, and at elevated temperatures. Since moisture does not penetrate their tough silicone jackets, they are now used for many installations that once required totally-enclosed motors. Silicone rubber insulated motors cost less to buy than equivalent totally-enclosed fan cooled motors, since there is no need for expensive enclosures.

But your savings don't stop with initial cost. When rated to match normal load, Wagner silicone rubber insulated motors deliver rated horsepower at top efficiency. They have more overload capacity for temporary overloads . . . reduce downtime while they help keep production levels up.

Like to hear the whole money-saving story of these dependable Wagner silicone rubber insulated motors? Call your Wagner Sales Engineer . . . then settle back for some profitable listening.

Wagner Electric Corporation
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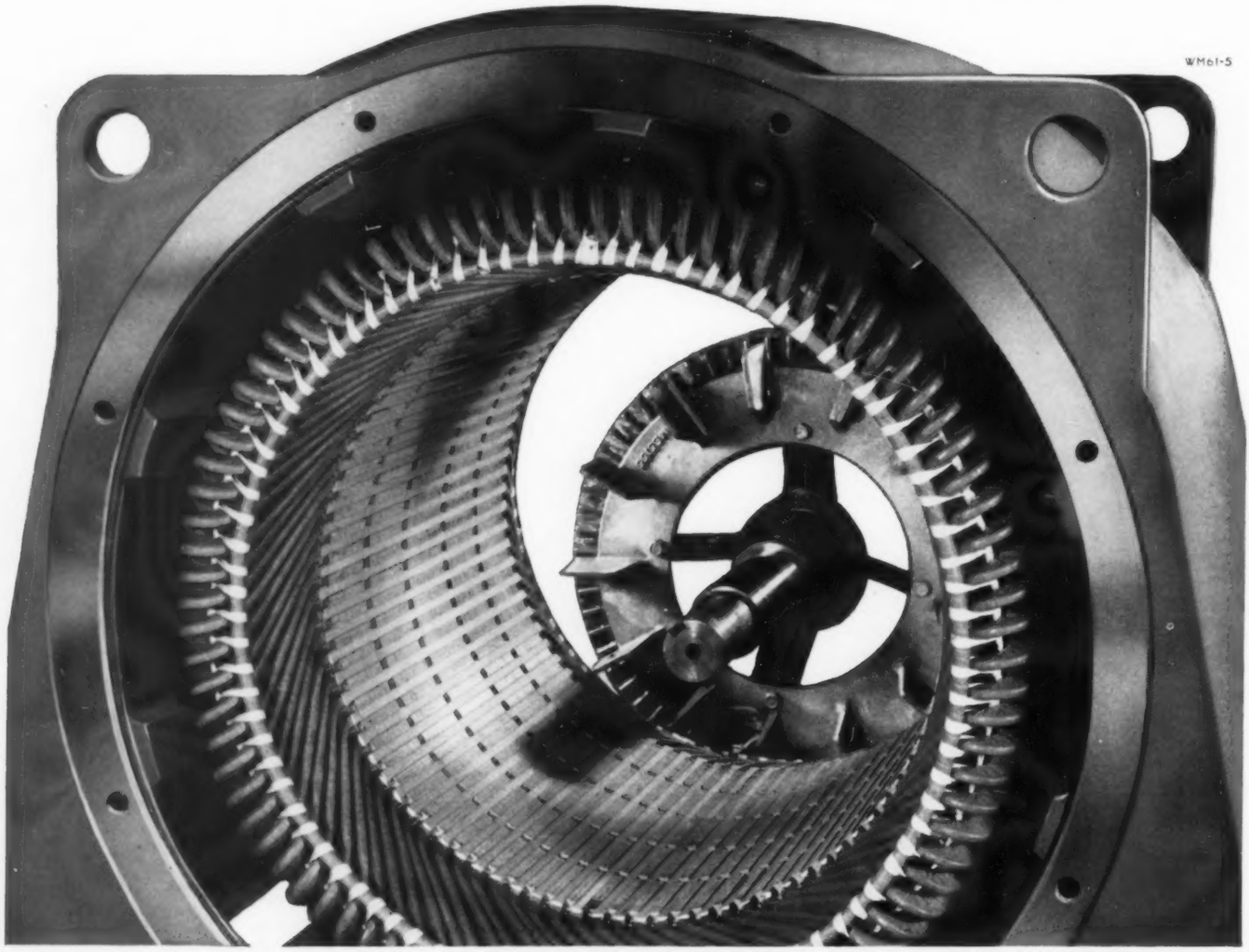
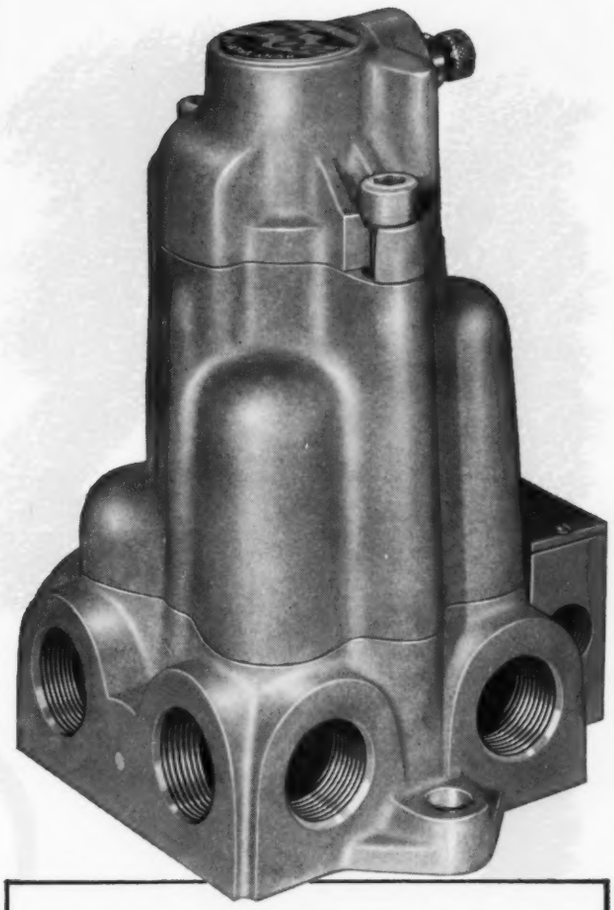


It's new! HUNT ONE INCH PDQ VALVE



Cylinder ports front, side and bottom-tapped; supply and exhaust ports side and bottom-tapped; basic 1 in. PDQ available tapped ¾, 1 or 1¼ in. NPT (also basic ½ in. PDQ tapped ⅜, ½ or ¾ in. NPT); for air or vacuum service, pressures from 0 to 125 psig; meets JIC Standards.

TOPS in accessibility
TOPS in simplicity
TOPS in speed
TOPS in capacity
TOPS in quality

Now you can have all the performance-proved advantages of Hunt's PDQ center-line design PLUS the high capacity of full 1" size. The PDQ's short stroke pilot and compact, lightweight, single spindle poppet provide lightning-fast response and near-instantaneous full flow. All this in a compact package weighing only 10.8 pounds!

Look at these performance figures. The 1" PDQ, with 100 psig supply, fills a 400 cu. in. vessel to 90 psig in but 0.288 seconds (17.3 electrical cycles) . . . exhausts the same vessel from 100 to 10 psig in 0.200 seconds (12 electrical cycles) and, at 100 psig, its flow capacity is 850 cfm free air!

Downtime? Short stroke, shock-reducing all-aluminum construction and built-in wear compensation assure millions of cycles of trouble-free operation. Then, to repack, simply loosen 2 cap screws . . . twist pilot cap . . . remove pilot and valve housing. Piping is undisturbed . . . electrical connections are plug-in, wiring need not be touched.

If you're looking for better, lower cost, more dependable performance on new or existing equipment . . . before you buy any valve, be sure you see the PDQ. Call your nearby Hunt Representative today. He's listed in Sweet's Product Design File.

For more information, write for Bulletin 602. Address Dept. ISE-561, Hunt Valve Company, Salem, Ohio.

HUNT

QUICK-AS-WINK® AIR AND HYDRAULIC

VALVES

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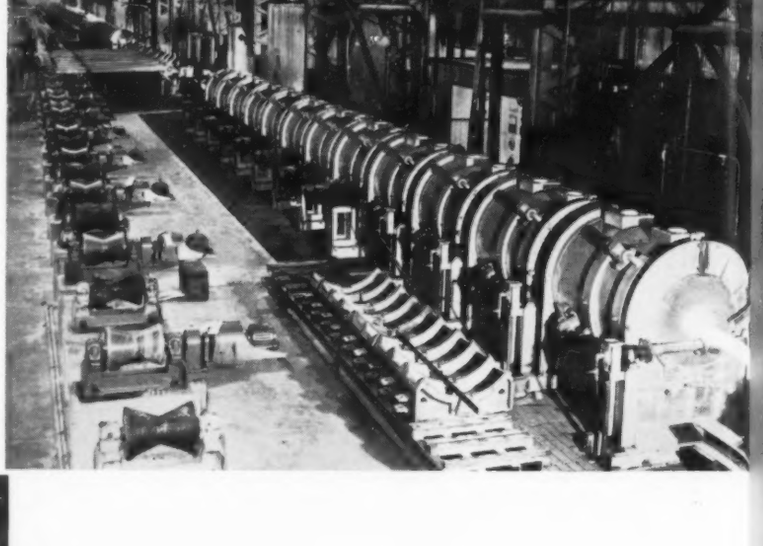
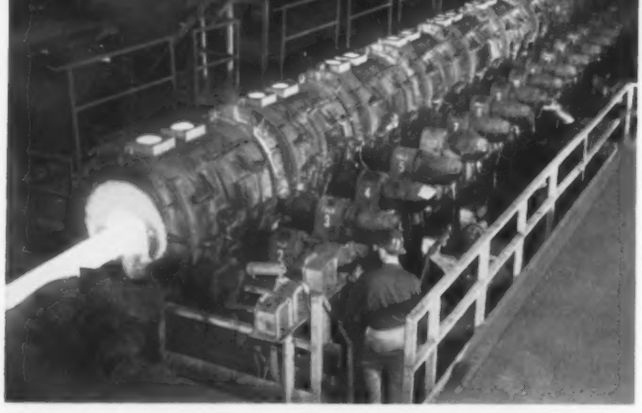
3010

NEW SLANTS ON HEAT PROCESSING FROM SELAS

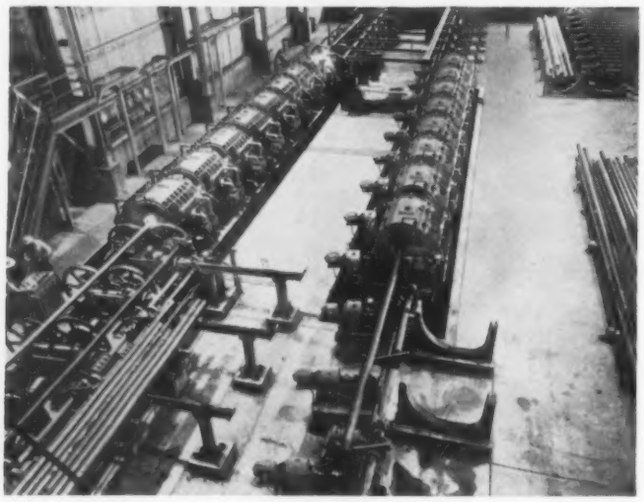
Here's how the Steel Industry relies



TUBING... *is normalized and, if required, stretch-reduced in this Selas barrel-furnace line. After forming and welding, the tubing is conveyed through a 48-barrel normalizing line with exit temperature approximately 1650° F. Stretch-mill product proceeds through 12 additional* GRADIATION® *furnaces which heat tubing to 1800°-1850° F. Entire process is automated, with line speeds matching mill speeds.*



BLOOM REHEATING *"on the fly," at rates of 198 tons per hour is accomplished in this continuous Selas barrel-furnace line. Reheating time of* only 3 minutes *reduces scale, amounting to a saving of 3 tons of steel per hour. Automated handling saved enough to pay for equipment in first 1½ months! Occupying floor area only 63' x 11', this continuous furnace assures uniform rolling temperature within each bloom and from piece to piece.*



SHORT-CYCLE HEATING *of seamless tubing for oil-country application is a typical cost-saving operation for Selas barrel-furnace lines. This overall view shows hardening (left) and tempering (right) lines, with automatic transfer between these treatments. Eight barrels per line. Advantages include: uniform properties throughout, little or no scale, reduced floor space requirements, and high degree of controllability.*

on Selas barrel-line furnaces

The installations on these pages graphically demonstrate how the steel industry relies on Selas barrel-furnaces to

- cut operating costs
- increase production rates
- reduce handling and labor requirements
- save valuable floor space
- improve product quality

Specifically designed and custom-built to meet individual production requirements and job specifications, Selas barrel-line furnaces employ time-proven standardized engineering features for long-time operating dependability and minimum initial investment. Acceptance? 446 Selas barrel-furnaces are at work in 49 separate heat treating lines for a variety of continuous applications including annealing stainless bars and tubing, heating billets for piercing, reheating pierced tubes for sizing, hardening and tempering oil country alloy and carbon tubing, etc.

At your convenience . . . without cost or obligation to you . . . a Selas field engineer would welcome the opportunity to survey your needs. For this personal service contact our Steel Mill Division Office, 300 Mt. Lebanon Blvd., Pittsburgh 34, or our Furnace Division, Dresher.

SELAS CORPORATION OF AMERICA

45 Dreshertown Road, Dresher, Pa.

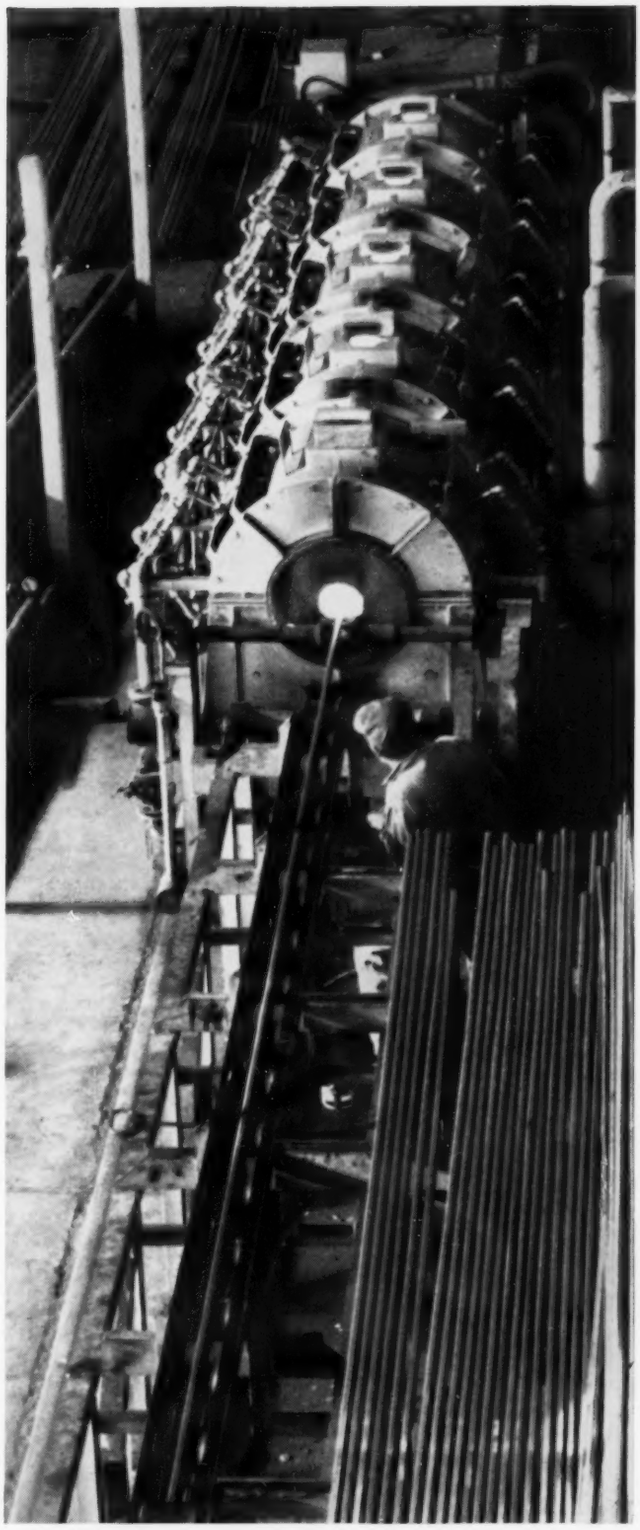
EUROPEAN SUBSIDIARY: Selas Corporation of America, European Div., S.A., Pregny, Geneva, Switzerland. INTERNATIONAL AFFILIATES: FRANCE—Societe Exploitation de Produits Industriels, Paris; JAPAN—International Machine Co., Ltd., Tokyo. BENELUX, PORTUGAL, SPAIN—Union Chimique, Brussels.

GRADIATION and DURADIANT are registered trademarks of Selas Corporation of America.

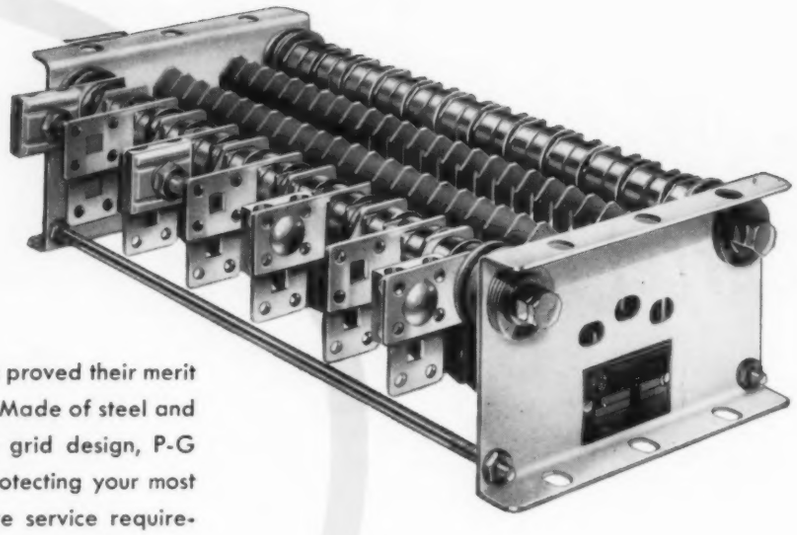
SELAS

HEAT AND FLUID PROCESSING ENGINEERS

DEVELOPMENT / DESIGN / CONSTRUCTION



STAINLESS STEEL *bars up to 5¼" cross-section and lengths to 30' are continuously annealed, and other grades normalized in this compact line of barrel-type furnaces.* DURADIANT® *burners heat uniformly at high thermal gradient without flame impingement on the work, resulting in minimum oxide formation. Annular ring water-spray quench cools work quickly and uniformly for maximum straightness in the annealed product.*



P-G STANDARD
Steel Grid Resistors

These rugged nonbreakable units have proved their merit in all kinds of service for many years. Made of steel and mica, plus P-G unique and exclusive grid design, P-G Standard Resistors are capable of protecting your most vital electrical equipment, even where service requirements are severe. Use of correct resistance value with ample capacity minimizes resistor trouble. ***Write for BULLETIN No. 500.***

P-G WELDED
Steel Grid Resistors

These units duplicate values of each P-G Standard Steel Grid Resistor. The only change is in adding welding links between resistance grids. Each welding link is made of the same alloy steel used for the grid. These links are heli-arc welded from grid to grid to create a continuous circuit without disruption to the normal path through contact spacers. Thus each P-G Welded Resistor has two paths available for carrying current. Naturally this offers double protection.

Write for BULLETIN No. 510.

P-G

ESTABLISHED 1892

THE **POST-GLOVER** ELECTRIC COMPANY

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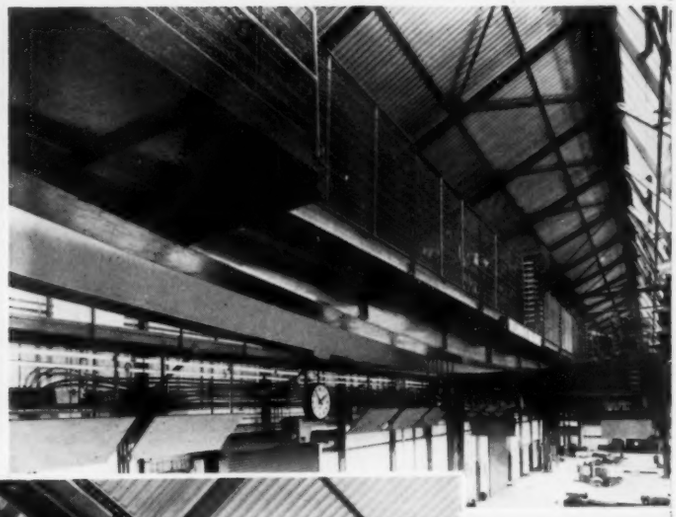
Once again Henry Wiggin & Company Ltd. order

WELLMAN CRANES

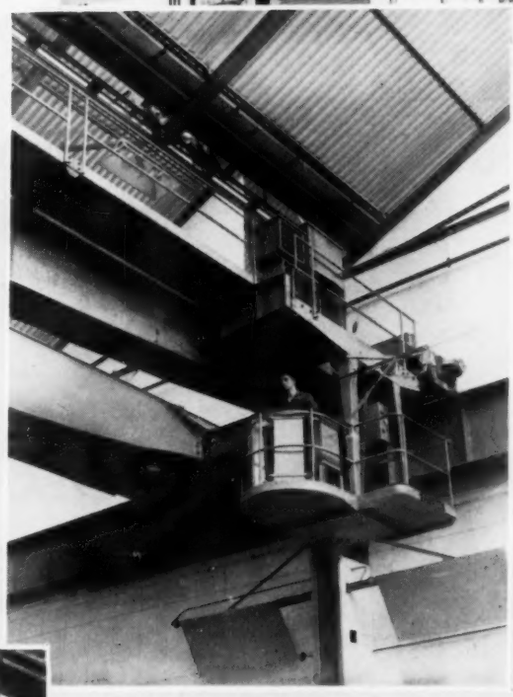
for their works at Hereford

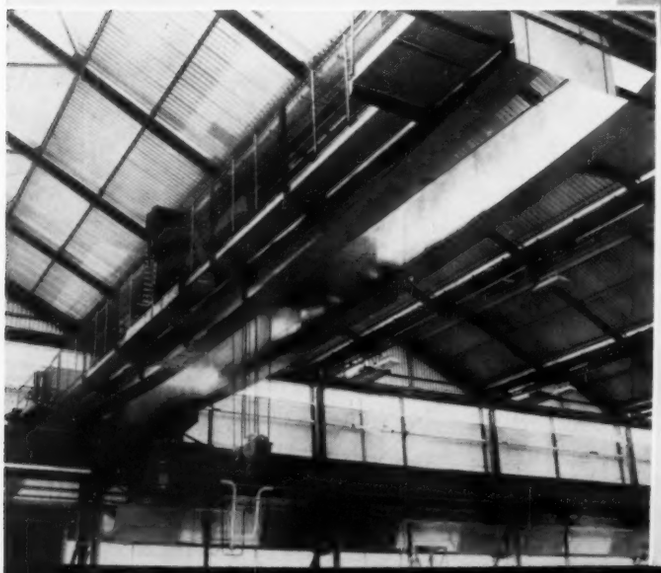


Henry Wiggin & Company Ltd., of Birmingham, Leading Nickel and Nickel Alloy Steel Manufacturers, continue to rely on Wellman Cranes.

Dependability, the hallmark of Wellman Cranes, is the very essence of continued full production.

First rate design team, three well-equipped manufacturing works, and complete shop erection before delivery to site, combined with many years of experience in both design and application, form the background of modern Wellman Cranes.





The photographs, by courtesy of Henry Wiggin & Company Ltd., show our latest box plate type girder resulting in low overall weight, high-speed travel and pleasing clean-cut design. The machine has a main hoist capacity of 15 tons, with auxiliary hoist capacity of 5 tons, has a span of 77 feet at a height of 25 feet above floor level.

THE WELLMAN SMITH OWEN ENGINEERING CORPORATION LTD.
PARNELL HOUSE, WILTON ROAD, LONDON, S.W.1 WORKS: DARLASTON, South Staffs, & BELFAST.

ELPAR TITAN

...For "big" truck maneuverability

Handles 15,000 to 20,000 pound coils ...will operate in box cars, narrow aisles and congested areas.

No other truck in this capacity range can match the TITAN series for maneuverability. Its as easy to operate as the family car and for maximum handling efficiency it is equipped with extra fast lift and travel speeds. Particularly valuable is the TITAN's fast accelleration which saves minutes when maneuvering in tight spots.

The Titan also establishes a new standard for dependability and easy maintenance that is unmatched by other trucks in the heavy duty class. You'll find a host of new safety features too.

There are four standard models—15,000 to 20,000 pound capacity—each one engineered to handle heavy loads faster and at lower cost.

Write for this TITAN Series Brochure—contains complete design and operating data.

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ELECTRIC TRUCKS

THE ELWELL-PARKER ELECTRIC COMPANY
4549 ST. CLAIR AVENUE • CLEVELAND 3, OHIO
In Canada: International Equipment Company, Ltd.

TWICE THE LIFE...ONE THIRD THE OPERATING COST

patent reviews

By MELVIN NORD, Patent Attorney, Detroit, Mich.

Copies of patents may be obtained from the Commissioner of Patents, Washington 25, D. C., at 25 cents . . . .
patents reviewed cover period December 20, 1960, to January 10, 1961

OXYGEN LANCE WITH BENT TIP

△ U. S. 2,965,370, issued Dec. 20, 1960, to Arthur J. Kesterton and Alan V. Williams, assigned to the Steel Co. of Wales, provides an oxygen lance for the roofs of open hearth furnaces.

The methods by which oxygen has previously been applied to open hearth furnaces have disadvantages in that the apparatus required has been located at positions around the furnace, such as the front or back, where it may seriously interfere with the normal processes of charging and tapping the furnace.

As shown in Figures 1A and 1B, the oxygen gun assembly 1 is supported by a cable 2 extending over a pulley 3, secured in the roof of a building containing an open hearth furnace indicated at 4. The cable 2 extends horizontally to another pulley 5 and down to the winding drums 6 of an electrically operated winch 7 secured to girders above the furnace.

The gun assembly 1 extends downwardly through an opening 8 in the roof 9 of the open hearth furnace 4. The opening 8 is in a panel of chrome-magnesite bricks 10 which is inserted in the roof of the furnace 4.

Located within the opening 8 is an annulus 11 which surrounds the gun assembly 1.

A guide 12 for the oxygen gun is positioned directly above the opening 8 upon a beam construction indicated at 13. The guide is for the purpose of assisting the cable in supporting the gun in position and

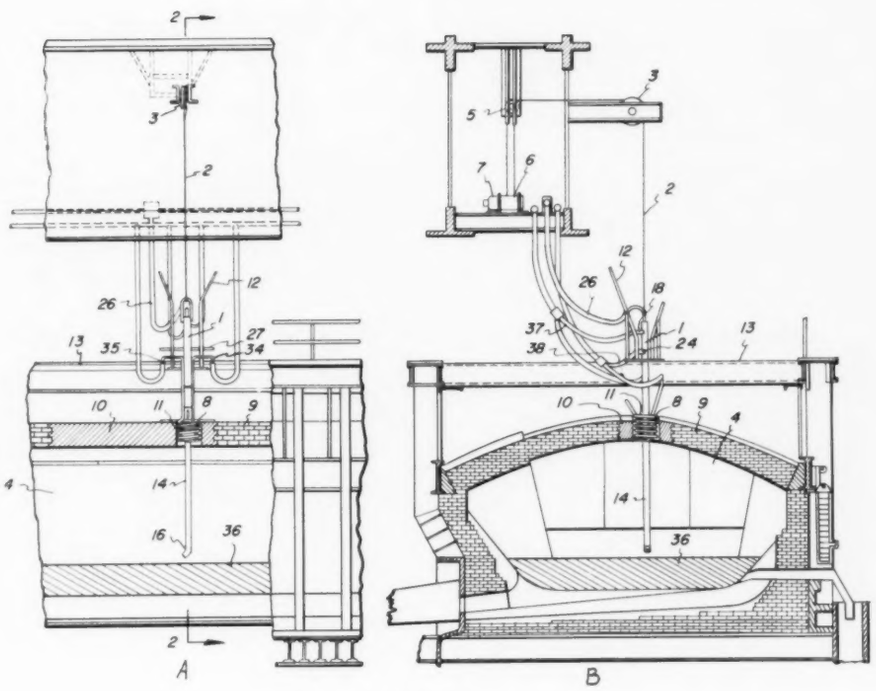

Figure 1

to prevent the gun from rotating within the furnace when it is in its operative position.

The gun assembly consists of a steel body 14 to which is affixed at the lower end thereof a copper nozzle. Extending from the upper portion of the gun body is a downwardly curved pipe 18 which is the inlet of the cooling water. The pipe 18 is connected to the open top ends of three pipes which extend the length of the oxygen gun and surround a centrally located pipe through which oxygen is passed.

A hose 37 connects the water inlet pipe 18 to a source of cooling water. A hose 38 connects to the water outlet pipe 24 to convey the heated water to a suitable cooling source. A hose 26 connects the oxygen pipe 20 to a source of oxygen. Near the upper end of the gun body 14 there is a pair of radially extending locating bars 27. These bars are of high-grade steel and are used to support and locate the gun in the gun guide 12.

Where it is desired to deliver oxygen to the steel bath within the open hearth furnace, the gun is lowered to the position as shown in Figures 1A and 1B. In this position, the nozzle of the oxygen gun is from

four to five in. above the steel bath indicated at 36. Since copper will melt at temperatures encountered within the open hearth furnace, water is circulated through the gun before the gun is lowered into the furnace. It is desirable to use copper for the tip of the gun, since copper is a good conductor of heat and will conduct the heat away from the nozzle of the gun as rapidly as possible.

It has been found that, by circulating the cooling water through the three pipes spaced around the central pipe through which the oxygen is delivered, the life of the gun is greatly increased. This increase is due to the high-speed turbulent flow of cooling water at the critical zone of the gun which is the extreme tip of the gun. The high-speed turbulent flow results in greater cooling efficiency at the tip of the gun where this property is most desirable.

When the gun has been lowered into position, oxygen is then passed through the central pipe 20. The oxygen is emitted from the gun at an angle and strikes the steel bath, sending up a spray of molten steel and slag. The angle at which the tip of the gun is bent is so selected that the slag which is thrown up by the jet of oxygen impinging upon the top of the steel bath just clears the tip of the oxygen gun. Since the oxygen diverges at an angle of approximately 7 degrees when it is emitted from the tip of the oxygen gun, it has been found that an angular bend of approximately 25 degrees will enable the reaction zone of the slag to just clear the tip of the oxygen gun when the tip of the gun is about five in. above the steel bath. As compared with a vertical jet direction, this greatly increases the number of "blows" which may be obtained prior to failure of the gun.

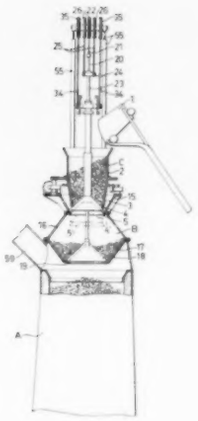

Figure 2

CHARGING DEVICES FOR SHAFT FURNACES

△ U. S. 2,965,249, issued Dec. 20, 1960, to Isak E. Johansson and assigned to T. An. Tesch A-B, relates to shaft furnaces equipped with a charging device comprising two hoppers, the upper hopper being rotatable. By the rotatable arrangement of the upper hopper, the stock supplied thereto is distributed uniformly around the circumference of the hopper before it is fed to the furnace.

As shown in Figures 2 and 3, A denotes a shaft furnace having a charging device comprising a lower hopper B and an upper hopper C.

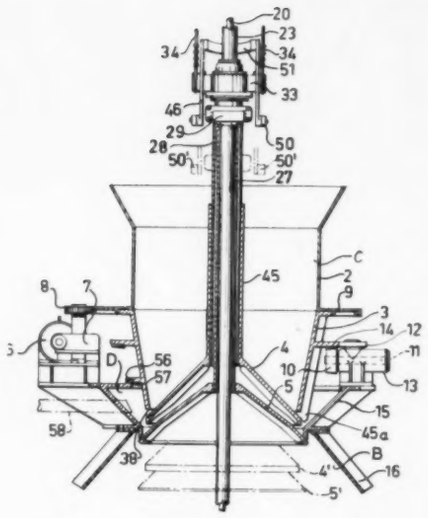

Figure 3

The stock to be charged is supplied to the upper hopper C by the skip car 1. When the upper hopper C is filled with stock, it is turned through a certain angle.

The upper hopper C comprises an upper cylindrical part 2, a lower conical part 3 and a bottom bell 4. These parts form the rotating assembly, the rotating movement of the parts 2 and 3 being imparted to the bell 4 by the intermediary of the stock introduced into the hopper C. The rotating movement is imparted to the hopper C by a driving unit anchored to the stationary part of the furnace and comprising an electric motor 6, an encased worm gear 7 and a gear wheel 8.

The lower hopper B comprises an annulus 15 which supports the driving unit and the supporting and guiding units of the hopper C and forms a circular lower opening for feed of the stock from the hopper C, lower opening for feed of the stock from the hopper C, an upper part 16 and a lower funnel-shaped part 17. At its top the hopper B is closed sealingly by the bell 5 when this is in its upper position, as shown in Figure 3. At its bottom the hopper B is closed by a bell 18 below which there is arranged a stock-distributing bell 19.

OTHER PATENTS OF INTEREST TO THE IRON AND STEEL ENGINEER

Patent No.	Date	Subject	Inventor or Assignee
2,965,209	12/20/60	Guide chute for hot strip coilers	United States Steel Corp.
2,965,216	12/20/60	Bar turnover for pack-annealing bed	Manuel Riesco
2,965,265	12/20/60	Compounding apparatus	United States Steel Corp.
2,965,328	12/20/60	Device for peeling strip metal from coils	Alvin F. Groll
2,965,478	12/20/60	Austenitic steel alloy	Allis-Chalmers Mfg. Co.
2,965,479	12/20/60	Non-ridging stainless steels	Universal-Cyclops Steel Corp.
2,965,521	12/20/60	Metal pickling solutions	Crucible Steel Co. of America
2,965,523	12/20/60	Scale removal from ferrous metal surfaces	The Dow Chemical Co.
2,965,526	12/20/60	Heat treating silicon steel	Westinghouse Electric Corp.
2,965,550	12/20/60	Coke oven door	United States Steel Corp.
2,965,960	12/27/60	Hot forming of metallic articles	Armco Steel Corp.
2,967,339	1/10/61	Ladle	Lukens Steel Co.
2,967,560	1/10/61	Corner bending corrugated sheet	Republic Steel Corp.
2,967,767	1/10/61	Iron powder composition for gas cutting, gas washing, and gas scarfing	Seiji Nishikiori et al
2,967,770	1/10/61	Stainless steel alloy	Republic Steel Corp.
2,967,790	1/10/61	Cleaning a hot top	Oblebay Norton Co.

[PRODUCTION OF FINE GRAINED METAL CASTINGS

△ U. S. 2,963,758, issued Dec. 13, 1960, to Guenter Pestel, Frederick C. Langenberg and Clyde R. Honeycutt, assigned to Crucible Steel Co. of America, provides a method and apparatus for refining the grain of

This forged alloy-steel sleeve is first heated to about 800 deg in order to expand its ID. Then it is lowered onto arbor, as shown. When the sleeve cools and contracts, it bites into arbor forming a tight fit.

Get more tonnage from back-up roll sleeves . . . make sure they're forged alloy steel

Our records show that a Bethlehem forged back-up roll sleeve on a modern continuous four-stand cold mill produces an average of 1,981,083 tons of cold-rolled sheets. Some have produced over 3 million tons! (And some of those are still going strong.)

Why this clear superiority over cast steel back-up rolls? Forged sleeves are denser and stronger. They offer greater resistance to spalling. You don't have to grind forged sleeves as frequently as you do cast steel back-up rolls, so you have much less downtime for roll changes. And you don't have to grind as deeply, so the sleeves last much longer. Result: more tonnage produced.

Bethlehem is well equipped to produce new sleeve and arbor assemblies; to replace used sleeves with new ones; and to install new sleeves on used back-up rolls. If you would like more information, get in touch with our nearest sales office. Or write to us at Bethlehem, Pa.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.
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Steel

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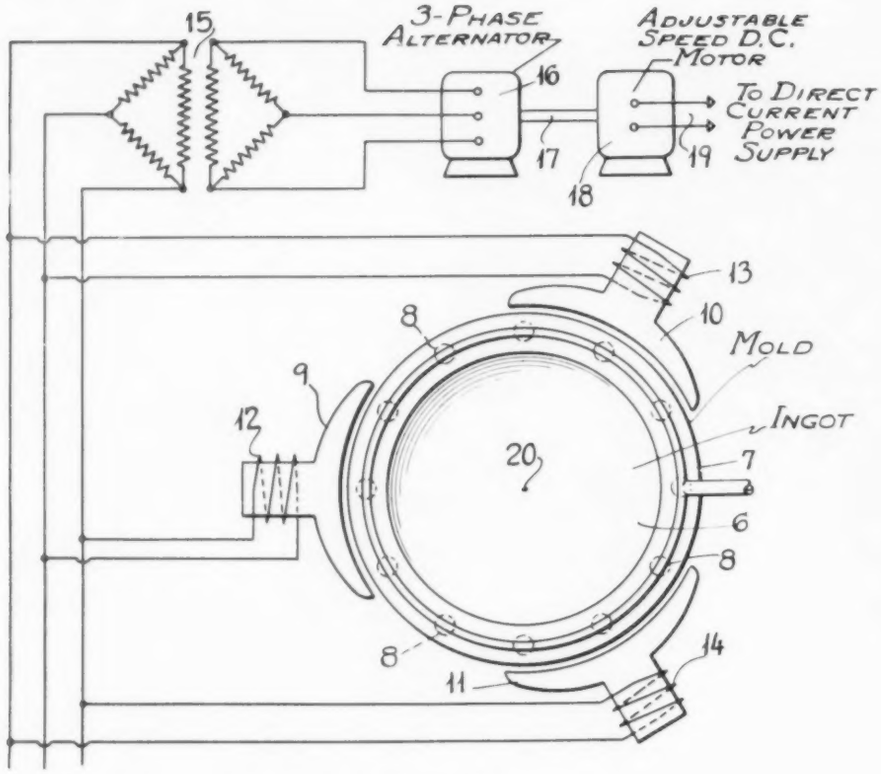


Figure 4

alloy steels and other metals which tend to form relatively large grains on solidifying from a molten condition.

It has been discovered that if molten metal, such as steel, is magnetically stirred within a nonmagnetic mold during cooling, the resulting casting or ingot has a refined grain structure and the formation of large columnar grains is prevented. In the preferred form of the invention, the molten metal is stirred electromagnetically in a direction extending transversely to the direction in which the columnar grains tend to form. The molten metal is stirred by an electromagnetic field which rotates about the entire length of an axis extending longitudinally and through the center of the molten mass. The magnetic field should be applied as soon as the liquid metal enters the mold in order that grain refinement can be achieved in the peripheral portions of the ingot. Otherwise, the initial cooling period will produce columnar grains extending perpendicular to the mold wall such that portions of cleavage planes are still formed in the ingot. In order to obtain optimum results, the field intensity of the magnetic field must be within a predetermined range, and the field intensity must be reduced in the latter stages of solidification in order to prevent the formation of center porosity in the mold. The apparatus used is shown schematically in Figure 4.

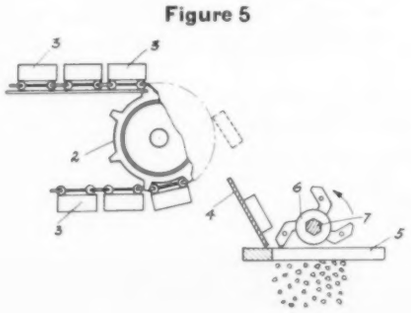
SINTER BREAKING APPARATUS

△ U. S. 2,965,321, issued Dec. 20, 1960, to Victor F. Koontz and assigned to Dravo Corp., provides a breaker for breaking sintered masses into pieces or chunks of a desired maximum size.

In Figure 5, 2 designates the sprocket at the discharge end of a sintering unit over which the succession of pallets 3 are carried and inverted so that the sinter cake falls from each down slide plate 4 onto the grizzly bars 5.

Cooperating with the grates is the crushing wheel designated generally as 6, and which is so positioned that the bars projecting from the hub of the wheel pass down between the bars 5 and break the sinter cake into fragments which can fall through the bars.

Figure 5



METHOD OF CLEANING IRON ORE FINES

△ U. S. 2,965,473, issued Dec. 20, 1960, to Charles Jully, assigned to Houilleres du Bassin de Lorraine, provides a method of cleaning iron ore fines for the production of ferrous coke.

As shown in Figures 6 and 7, a coke quenching station comprises the coke quenching car 1 co-acting with an auxiliary car 2 for distributing the iron ore fines to be cleaned; this auxiliary car 2 is fed with iron ore fines from a silo 3 and adapted to distribute a uniform layer 6 of iron ore fines over the batch of incandescent coke in the quenching car 1 by moving along rails 4 carried by car 1. After charging of auxiliary car 2 with iron ore fines and distribution of the fines

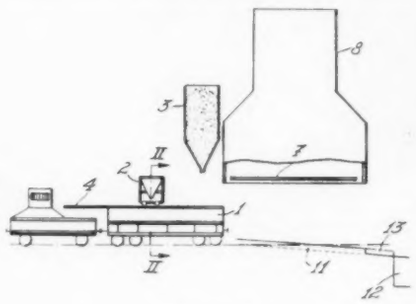


Figure 6

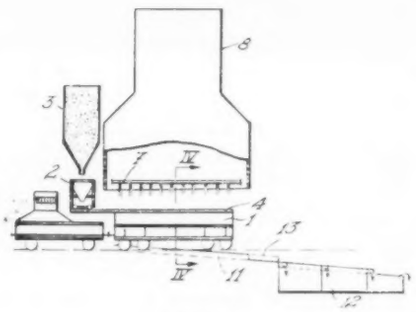


Figure 7

on the batch, the quenching car 1 is quickly moved from the oven under the sprinkling distributor 7 below the quenching tower 8, which will quench the incandescent mass. The quenching water utilized for this purpose acts as a washing water and becomes charged with the treated iron ore fines and with coke breeze and will subsequently flow under the swing door of the quenching car 1 into a canal 13 which feeds

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clear ponds 12 after passing over screening means 11. After the quenching step has been performed and the quenching water has flowed into canal 11, the quenching car 1 is brought back to an inclined wharf where it is dumped in the conventional manner by opening the swing door.

In the collected washing water the ore fines are separated, on the one hand, directly from the soluble parts of the inerts and, on the other hand, by gravimetric separation from the parts of the inerts which were burst, flashed and separated from the ore fines during the decarbonation and partial reduction of the fines under the action of the sensible heat of the incandescent coke.

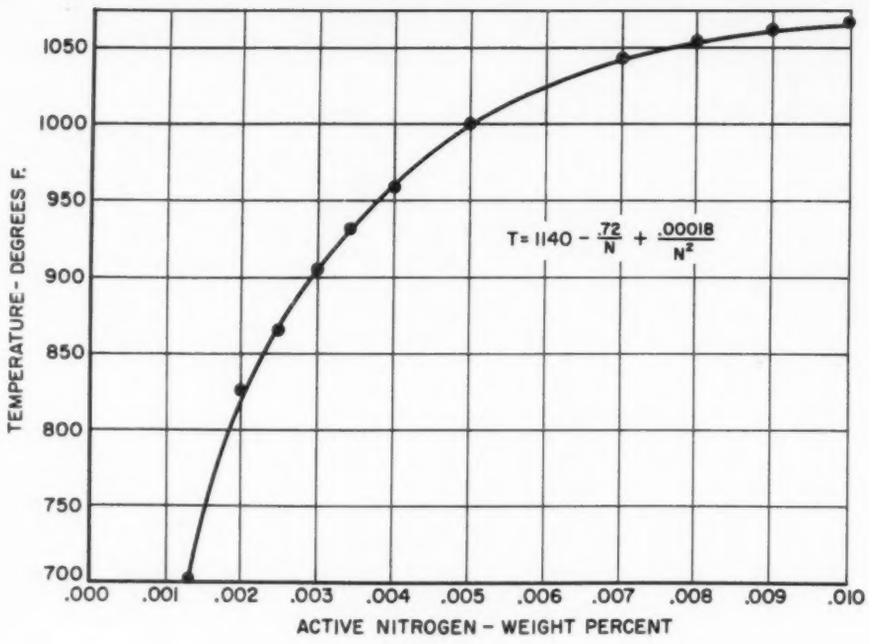

Figure 8

ALUMINUM CLADDING OF STEEL

△ U. S. 2,965,963, issued Dec. 27, 1960, to Walter Batz and James W. Thurman and assigned to Jones & Laughlin Steel Corp., describes a process for producing aluminum clad steel with a high degree of ductility.

It has been discovered that when a steel base is mechanically clad with an aluminum coating, the composite material so formed may be heat treated to bring about a strong metallurgical bond between the aluminum and the steel without the formation of brittle iron-aluminum alloy if the heat treating temperature is controlled in accordance with the active nitrogen content of the steel base.

The permissible heat treating temperature varies directly, although not linearly, with the active nitrogen content of the steel base. The relationship is shown in Figure 8.

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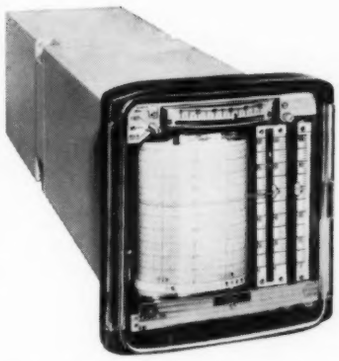

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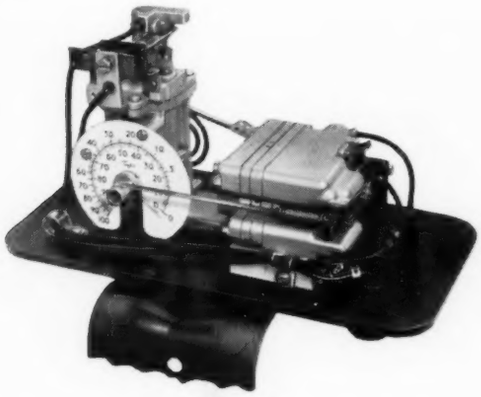

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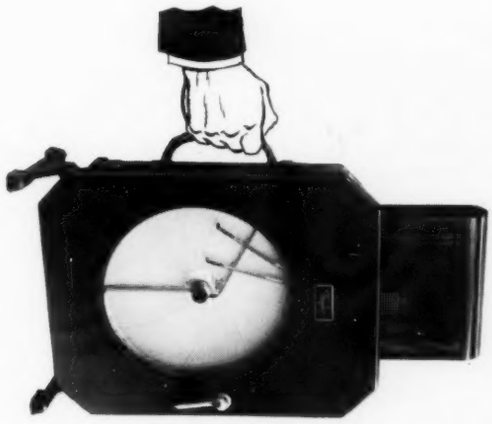

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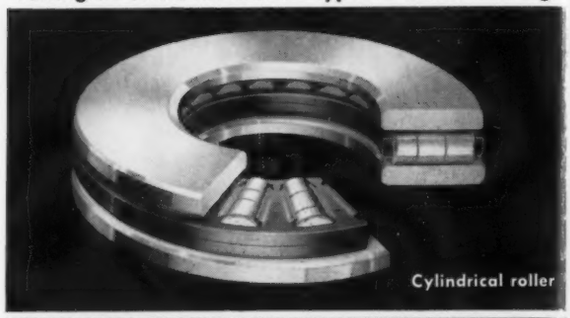
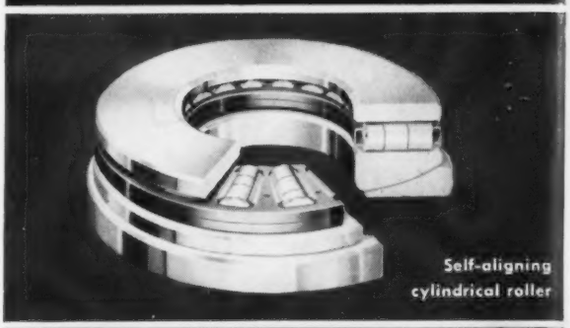
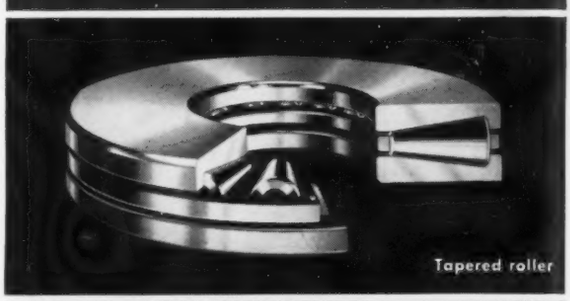
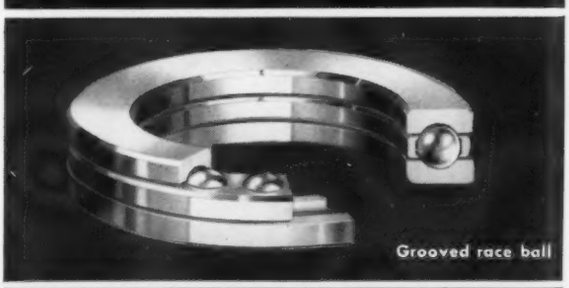
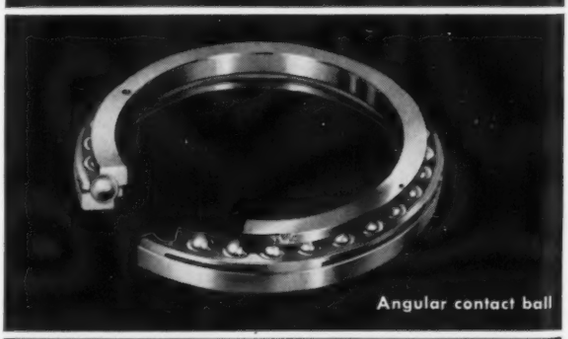
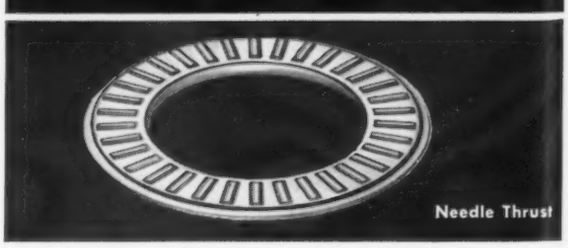

Cylindrical roller


Self-aligning cylindrical roller


Tapered roller


Grooved race ball


Angular contact ball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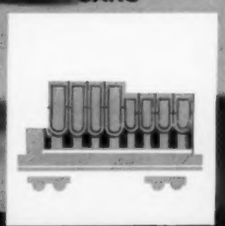

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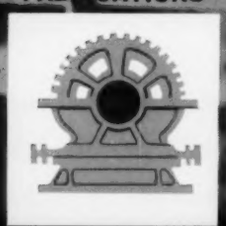

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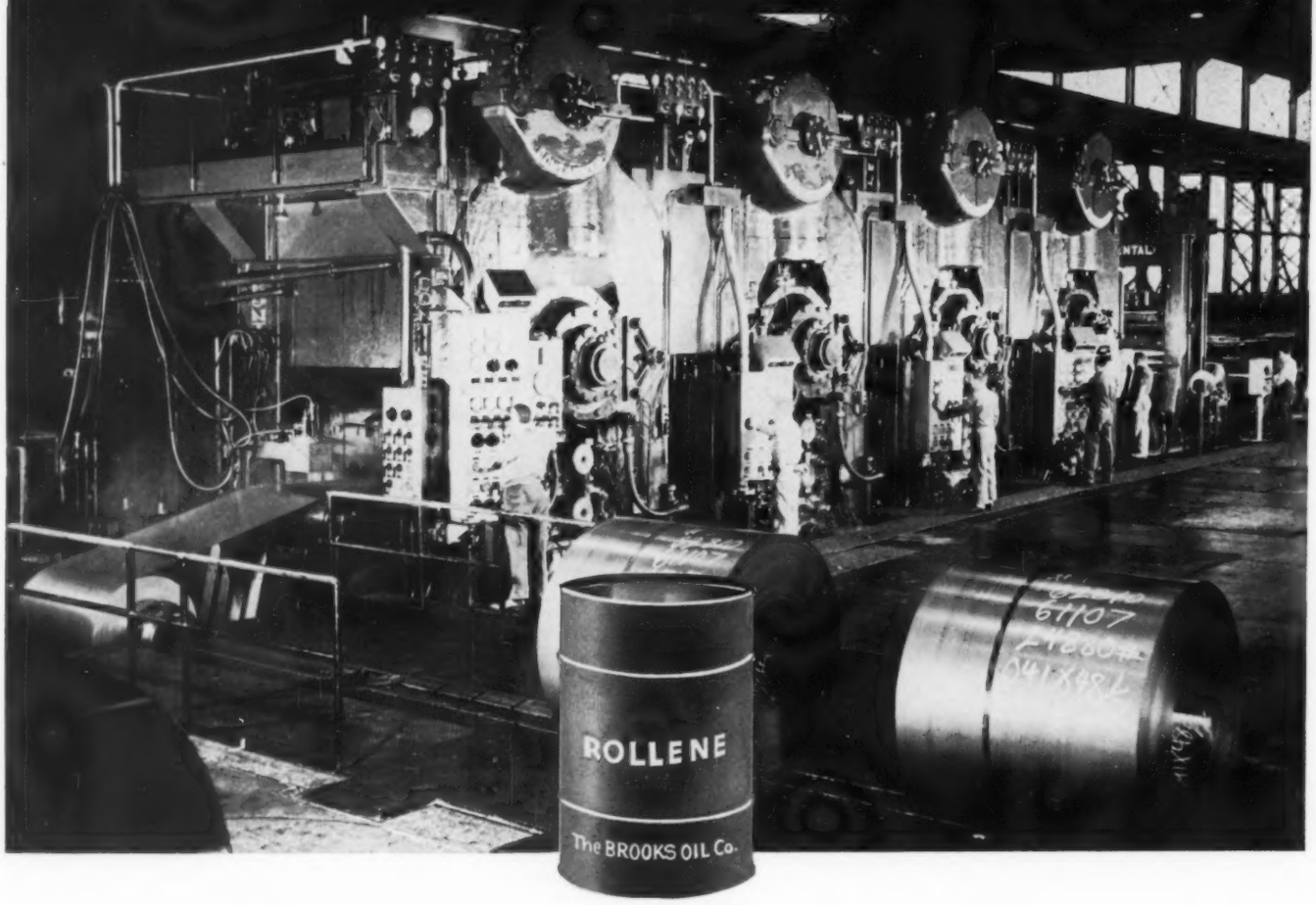

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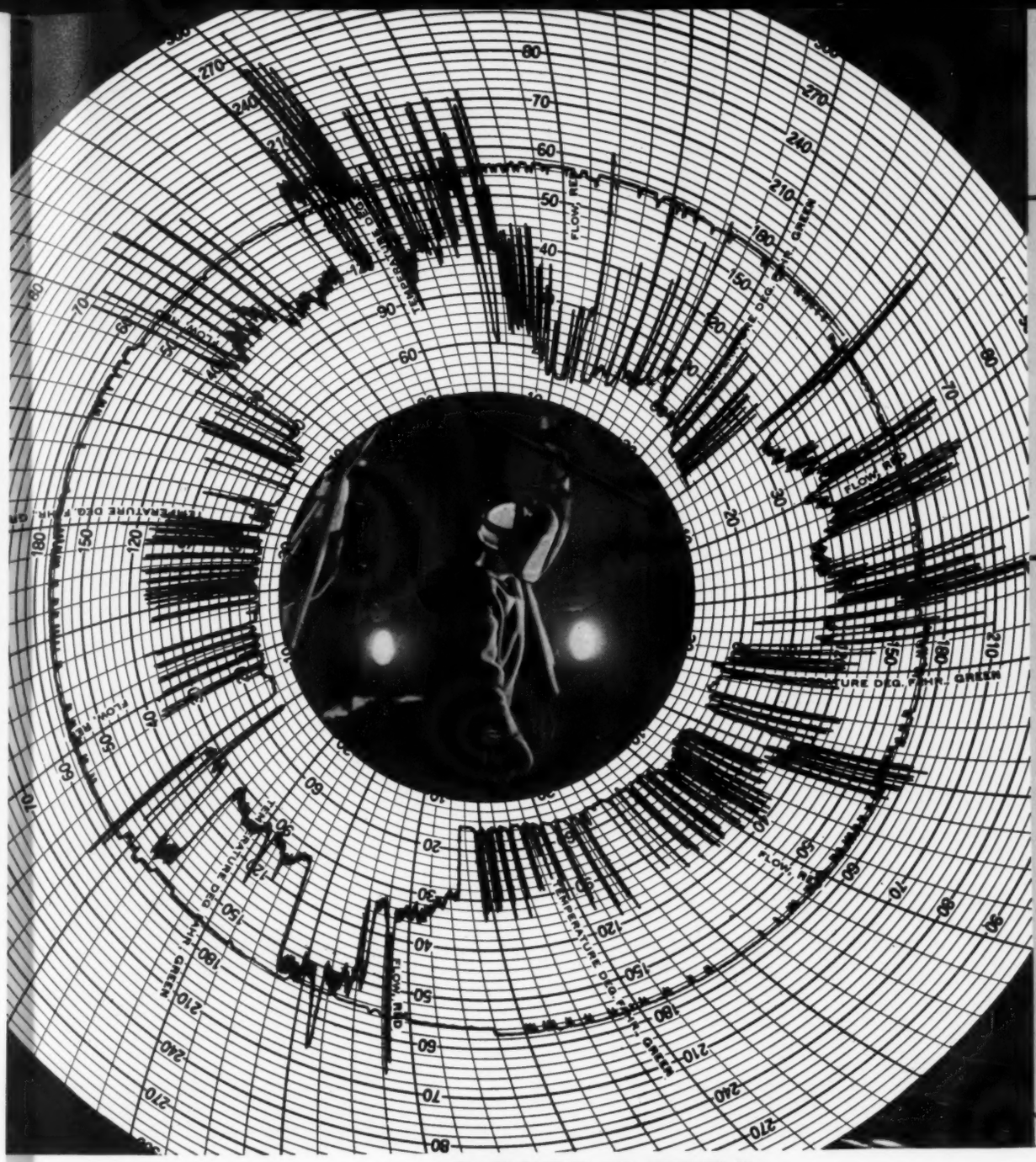

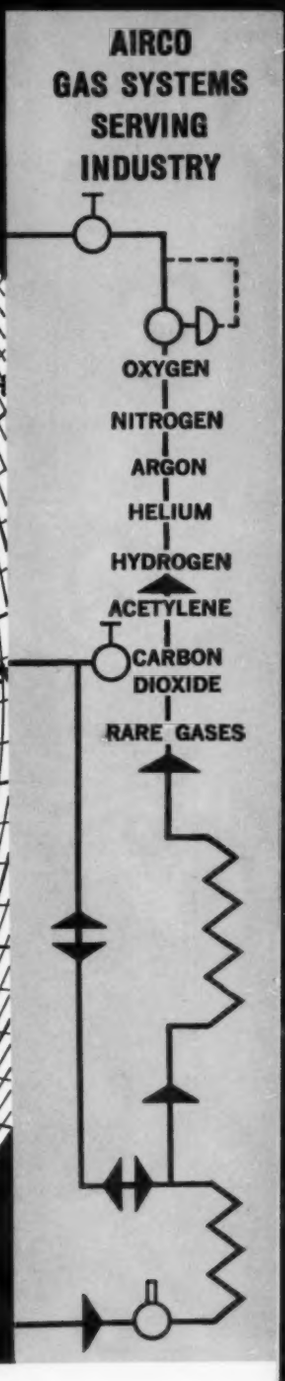

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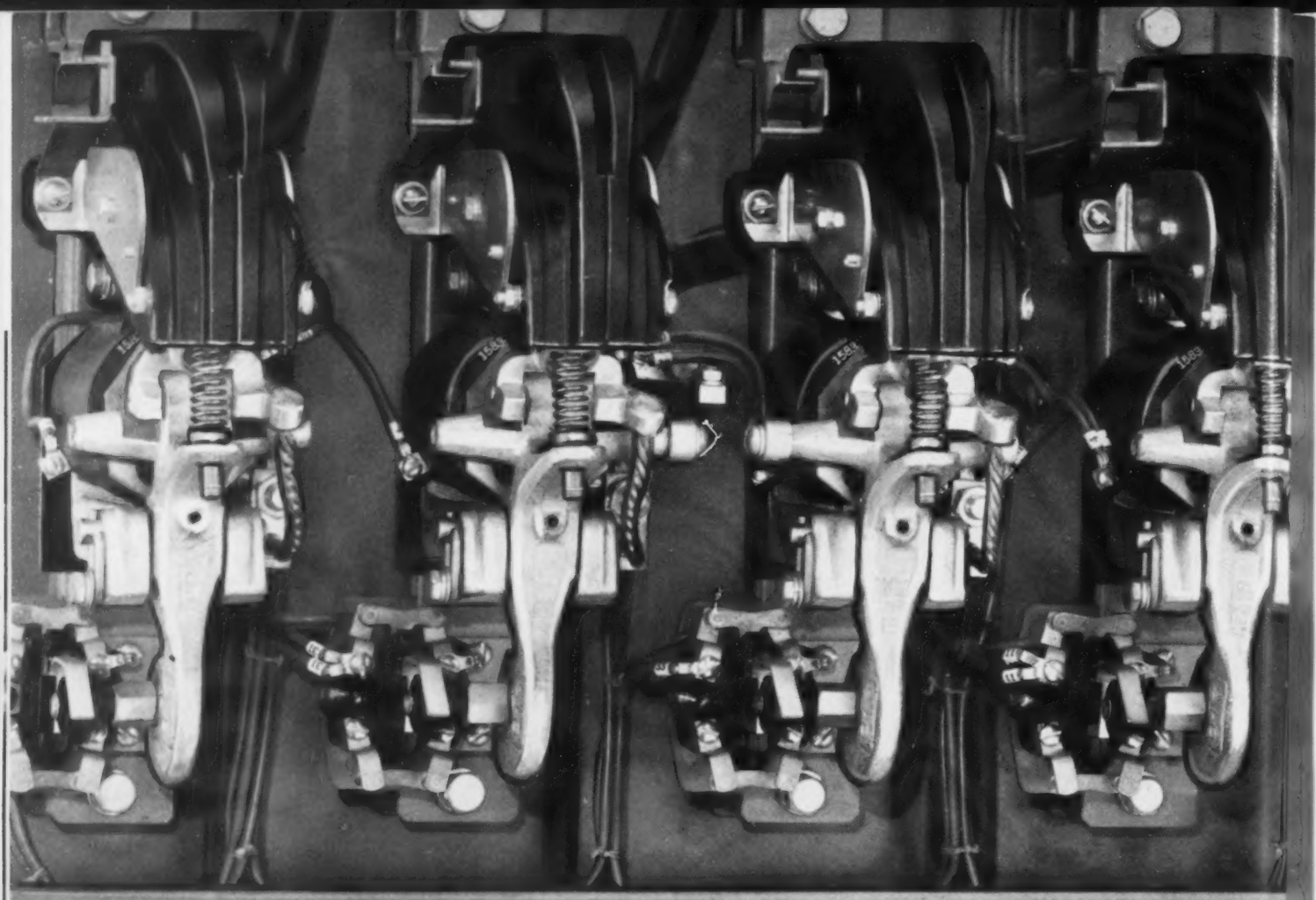

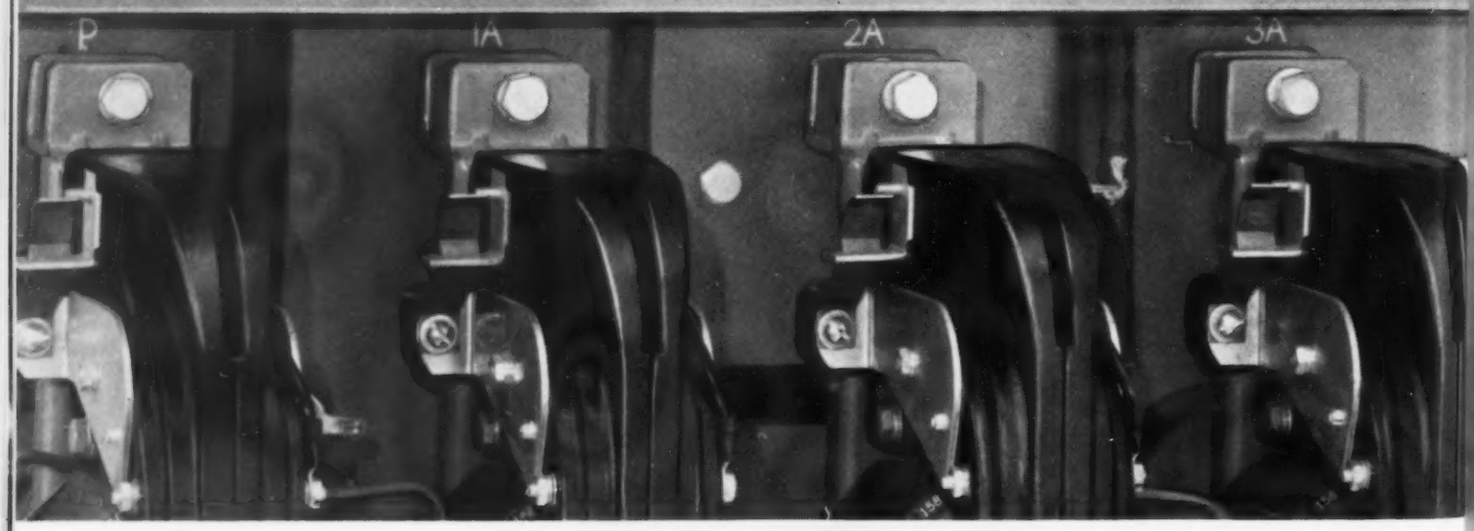

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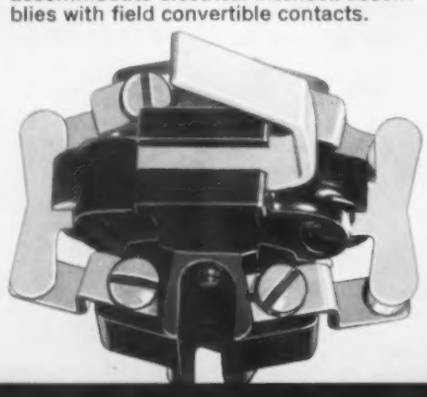

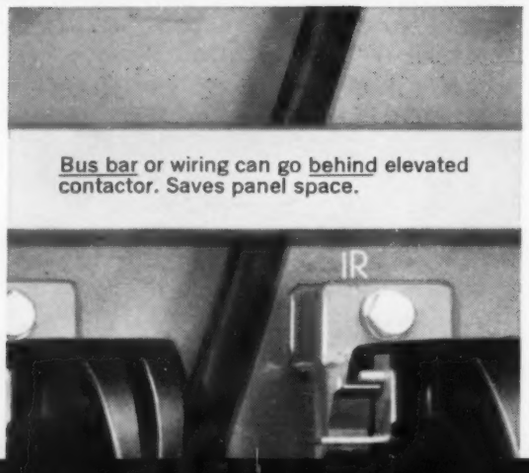

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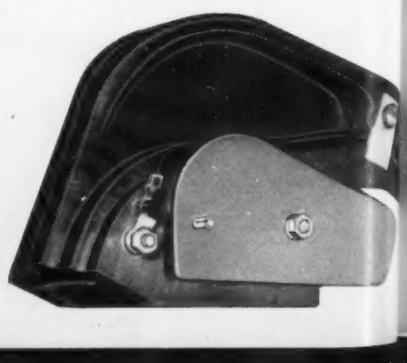

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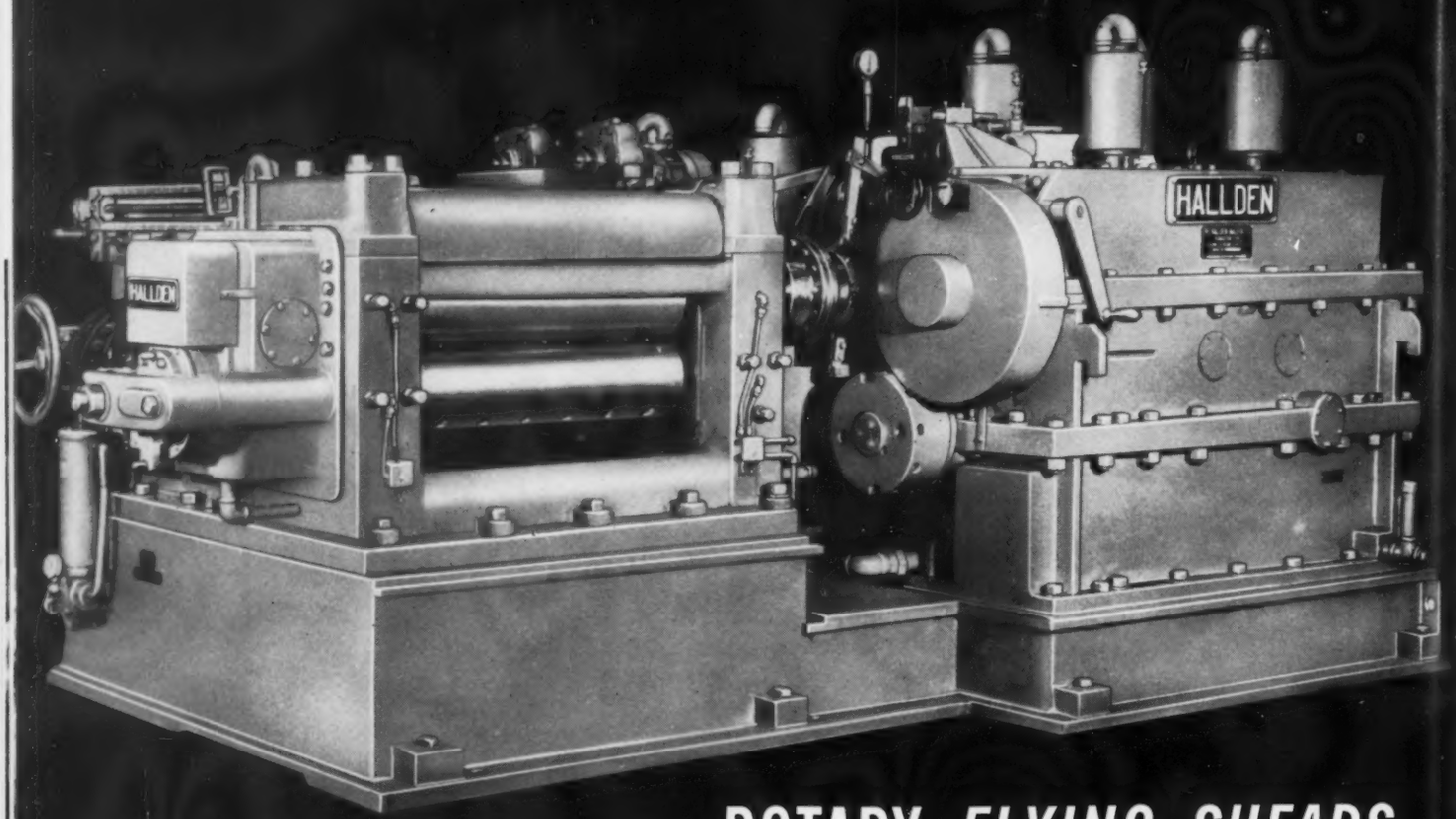

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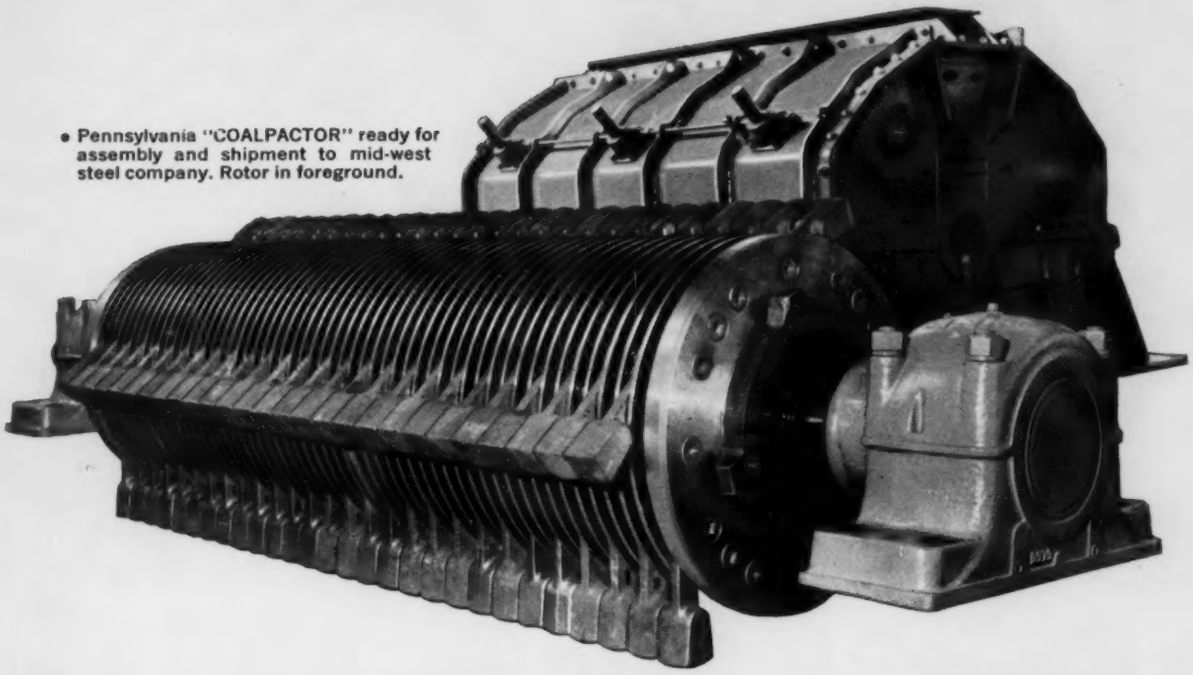

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Based on broad experience with hundreds of coke plant installations of Pennsylvania Impactors and Hammermills, Pennsylvania has now designed the new "COALPACTOR" incorporating the most desirable features of each . . . and planned specifically for preparation of coal for by-product coke plants.

Thorough laboratory and field tests have so convincingly proved the "COALPACTORS" advantages that already many units have been installed in major plants. More are on order.

Check over the 8 "COALPACTOR" advantages listed at left. If these interest you, we'd be glad to tell you more. Just write and ask for the full story on "COALPACTORS"—including specific results of coal pulverization field tests under typical conditions. Or a Pennsylvania field engineer would be glad to call if you wish, and discuss your coal preparation problems.

PENNSYLVANIA CRUSHER DIVISION

BATH IRON WORKS CORPORATION
WEST CHESTER, PENNA.

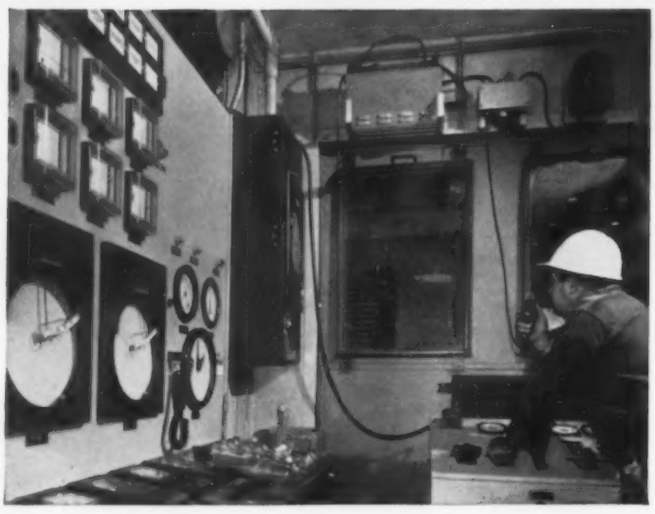
★ ★ ★

Over 50 years' concentrated experience in all types of material reduction. Call on Pennsylvania with your next crushing problem. Representatives from coast-to-coast.

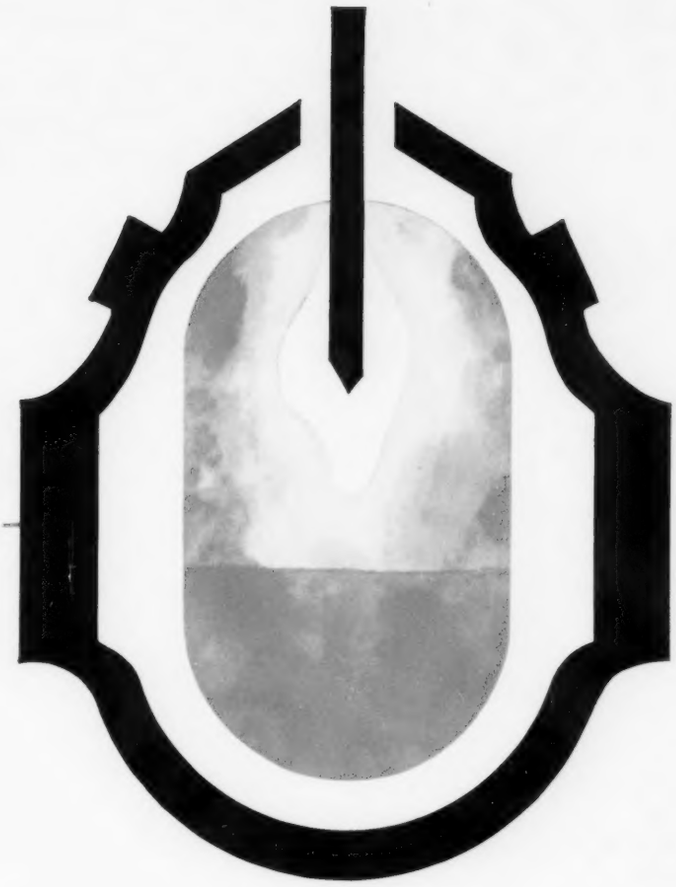
"COALPACTOR" is a registered trademark of Pennsylvania Crusher Division.

PENNSYLVANIA CRUSHERS

BATH-BUILT



At Kaiser Steel Corporation, Fontana, California, this Honeywell system helps double plant capacity by controlling oxygen mass flow, lance position, lance cooling water temperature and pressure, and other critical variables. At left, an operator watches charging of one of the three new oxygen converters from a window in the control pulpit.



Why did Kaiser select Honeywell instrumentation for its L-D process?

At the Fontana plant of Kaiser Steel Corporation, Honeywell instruments were selected for the new basic oxygen steelmaking shop. This new process required instruments that were accurate, reliable, and fast enough to deliver the precise integrated control needed.

Kaiser Engineers called on Honeywell to furnish the necessary control instruments.

If you're planning to use the oxygen process—in converter or open hearth—you'll find it profitable to have Honeywell design your entire control system, complete from primary elements to computer, and tailored to the particular requirements of your mill. Your nearby Honeywell field engineer can give you complete details. Call him today—he's as near as your phone.

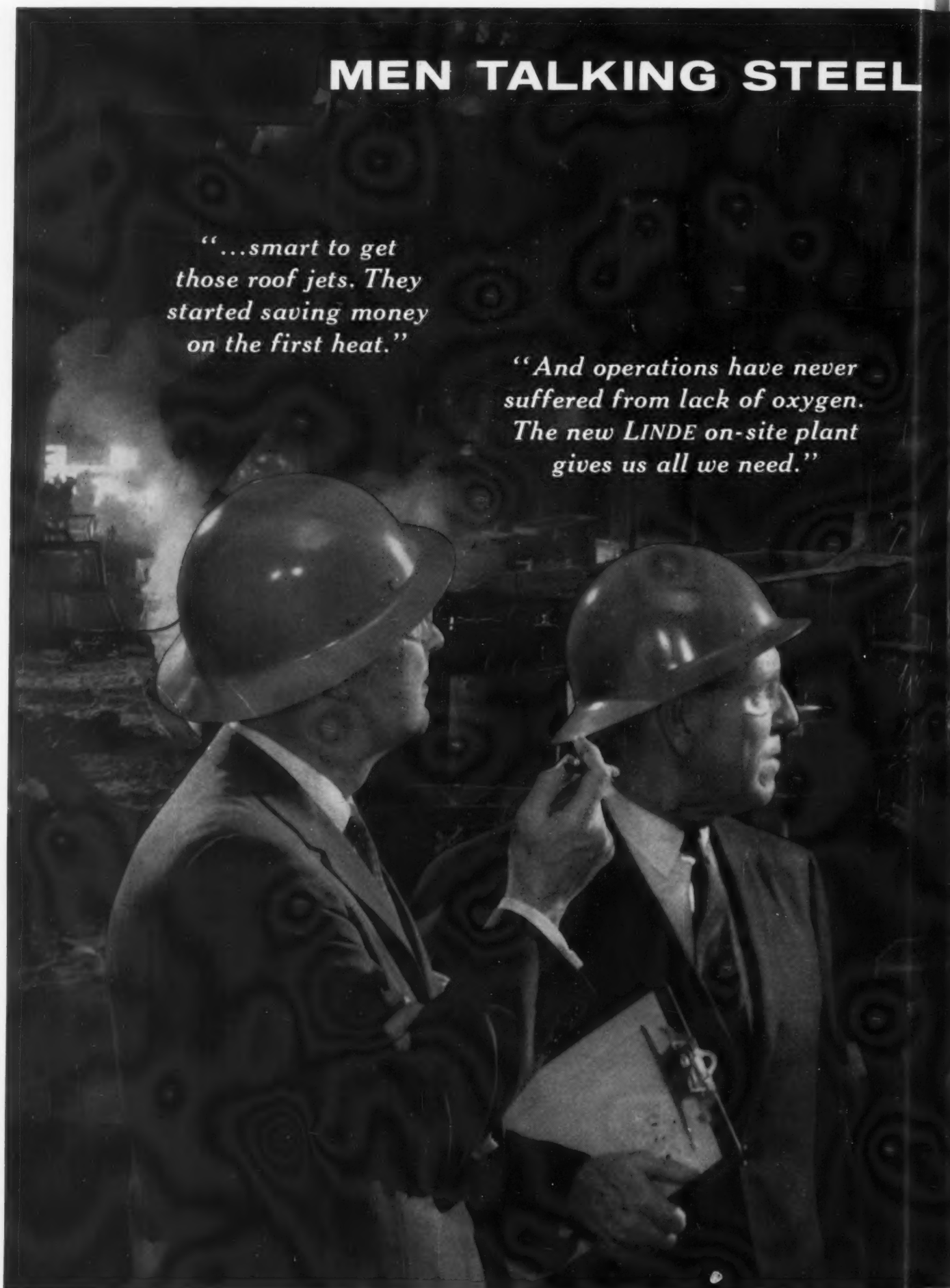
MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa. In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.

Honeywell

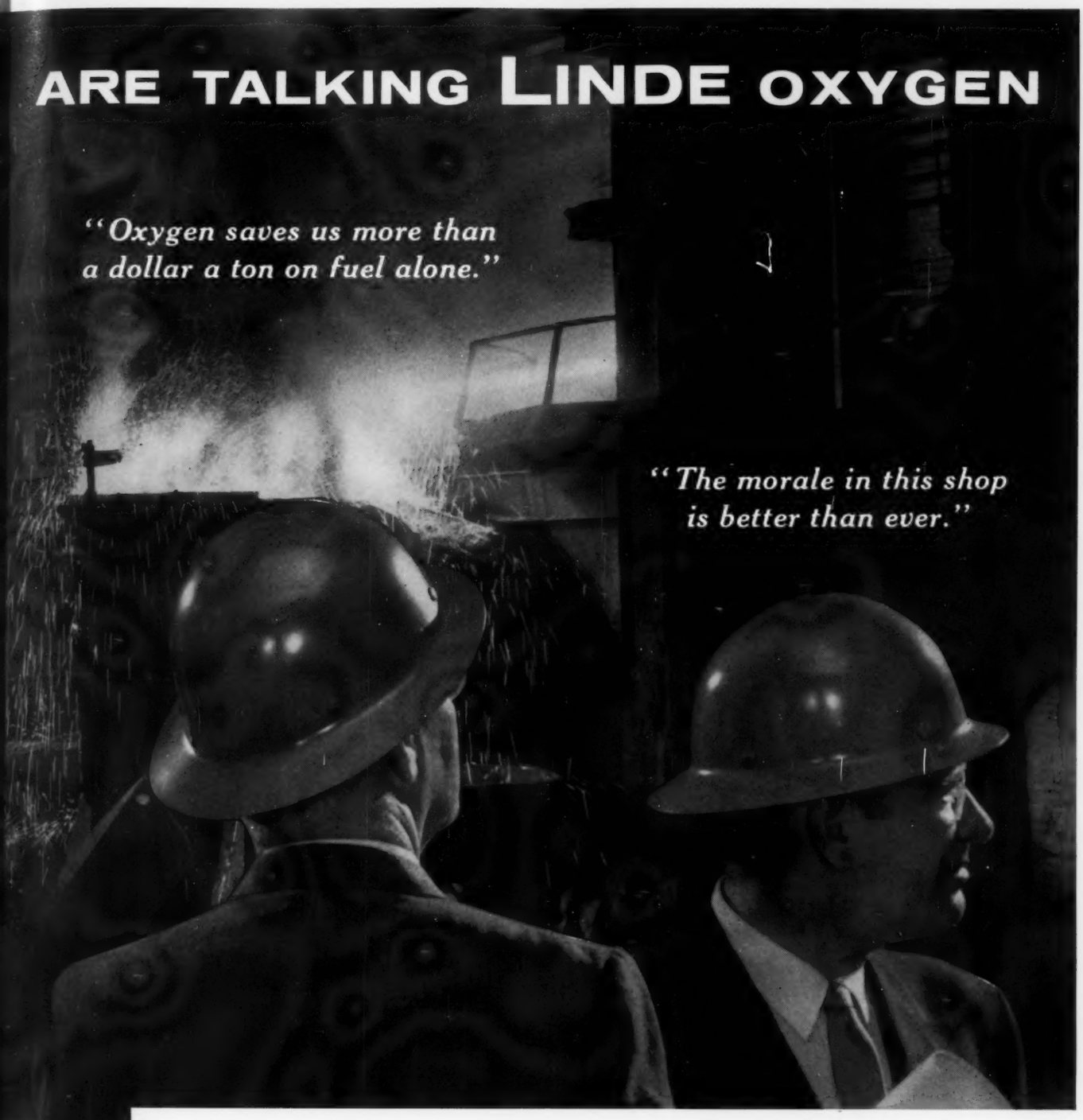
First in Control

SINCE 1885

HONEYWELL INTERNATIONAL Sales and Service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.


MEN TALKING STEEL
"...smart to get those roof jets. They started saving money on the first heat."
"And operations have never suffered from lack of oxygen. The new LINDE on-site plant gives us all we need."

L ARE TALKING LINDE OXYGEN

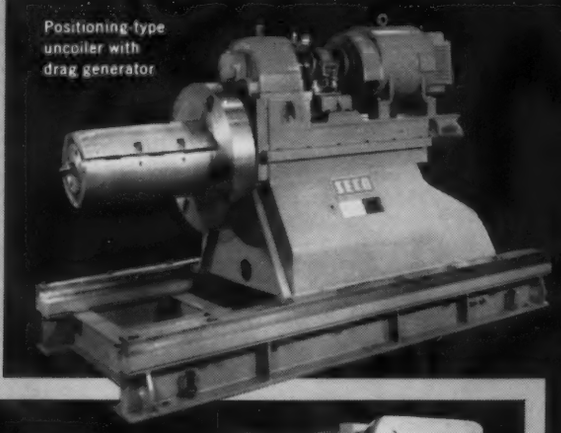


It takes LINDE to apply "*total gas technology*" to steelmaking, and you can get the facts that prove it by writing Linde Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, N. Y. *In Canada:* Union Carbide Canada Limited, Linde Gases Division, Toronto 12.

LINDE COMPANY

UNION CARBIDE

"Linde" and "Union Carbide" are registered trade marks of Union Carbide Corporation

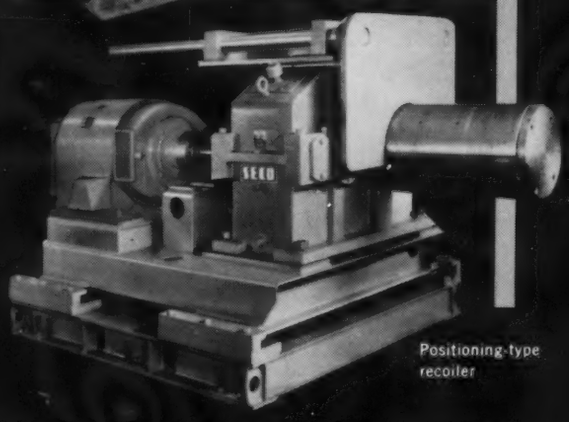


Predictable Performance

for processing lines with

SECO

terminal equipment

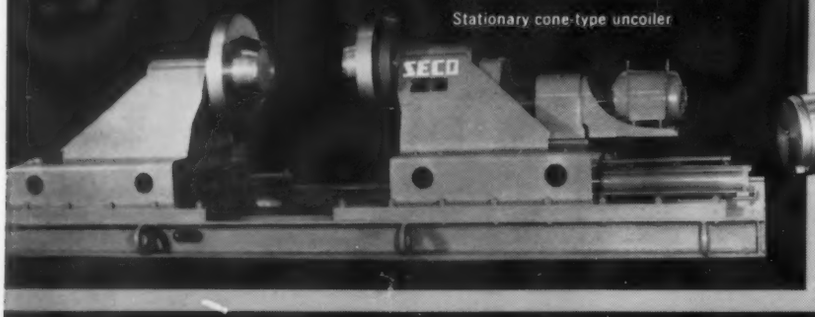


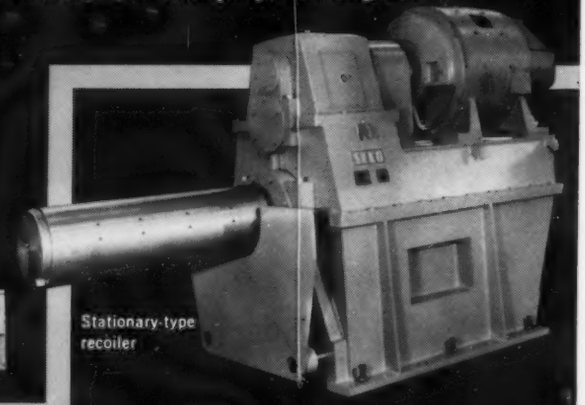
From entry to exit, new and modernized processing lines . . . annealing, pickling and others . . . perform better with SECO terminal equipment. This equipment handles coils ranging from 10,000 to 50,000 pounds with speed, convenience, safety.

SECO uncoilers and recoilers are designed to operate at any speed the mill requires, are available in positioning or stationary types. The positioning types feature a slideable reel base mounted on a sub-base for alignment with the processing line, actuated by an automatic edge control.

SECO also makes auxiliary equipment such as coil cars with coil lifts to simplify uncoiler loading and recoiler unloading. Available for mandrel or cone-type reels.

A staff of trained sales engineers will assist you in finding the equipment best suited to your needs. Call or write today. West Coast representative: United Machine Tool Company, Los Angeles.





SECO STEEL MILL EQUIPMENT

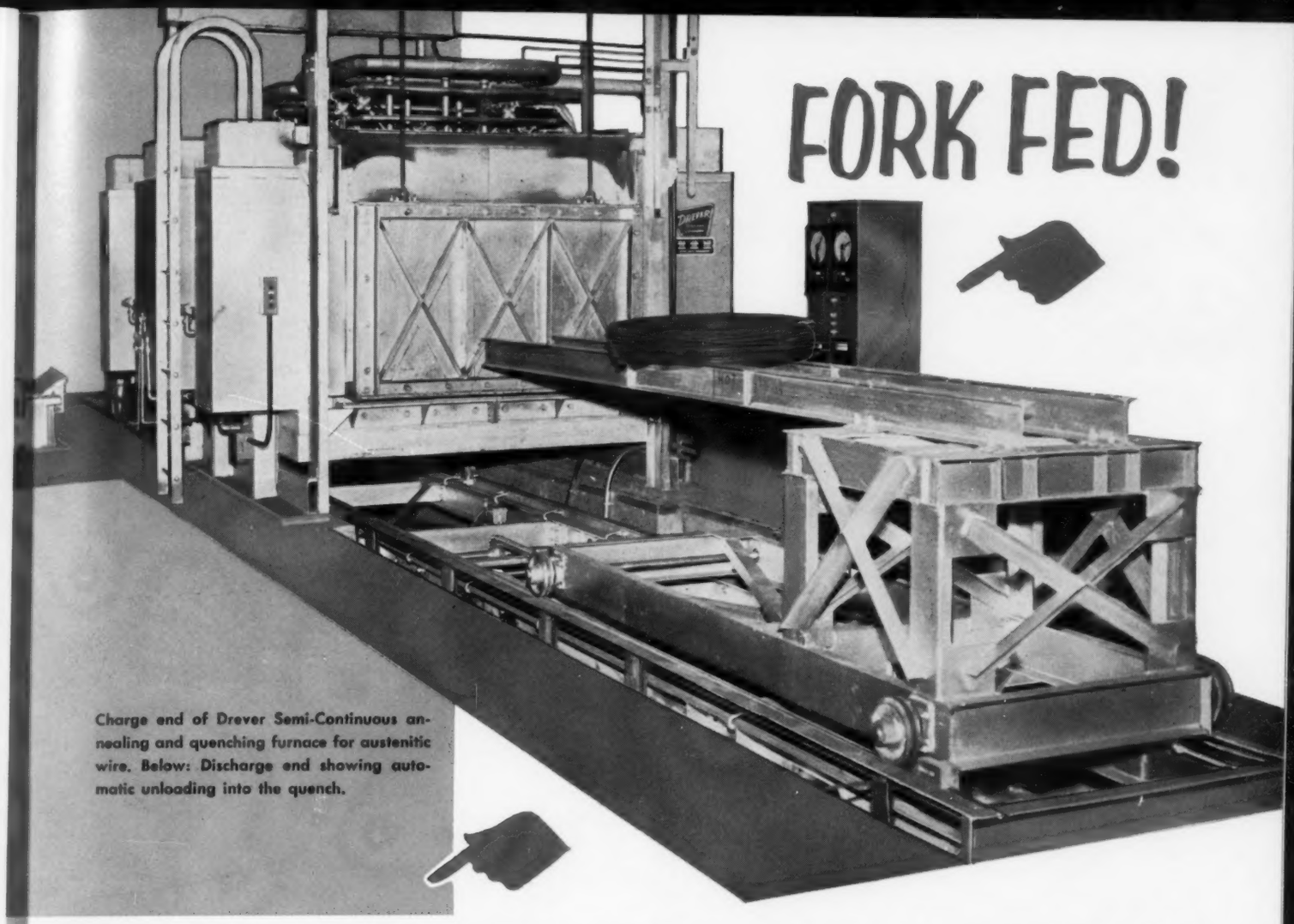
- Leveling and Shearing Lines
- Combination Edging and Flattening Lines
- Tension Reels for Strip Polishers
- Narrow Strip Grinding Machines
- Slitting Lines
- Multiple Strand Pull-out Rolls and Take-up Frames
- Strip Coilers (Up and Down Type)
- Traverse Reels for Narrow Strip
- Steel Coil Up-enders
- Scrap Ballers

STEEL EQUIPMENT COMPANY

P. O. BOX 737, WARRENSVILLE STATION • CLEVELAND 22, OHIO

Affiliated with Lee Wilson Engineering Co., Inc.

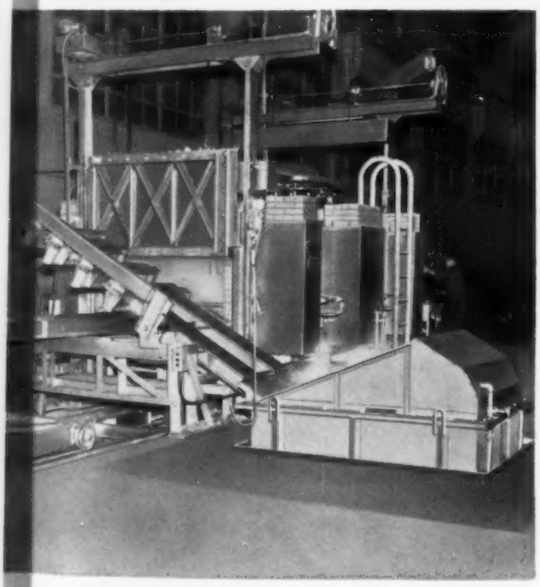
FORK FED!



Charge end of Drever Semi-Continuous annealing and quenching furnace for austenitic wire. Below: Discharge end showing automatic unloading into the quench.

DREVER STAINLESS WIRE COIL ANNEALERS

For semi-continuous annealing and quenching



A push of a button after the operator has placed the coil on the charging fork sets off the complete automatic operation of this Drever Furnace handling austenitic stainless steel wire in coils. It is Drever engineered to process coils through both furnace and quench on the basis of a short heating cycle and minimum scale build up.

DREVER ADVANCED ENGINEERING

Complete heat treating systems that can meet today's higher and higher requirements for product quality combined with the economic necessity for semi-continuous or completely continuous operation, demand the design knowledge of highly specialized engineers. The Drever engineering staff has had extensive experience in every phase of industrial furnace engineering.

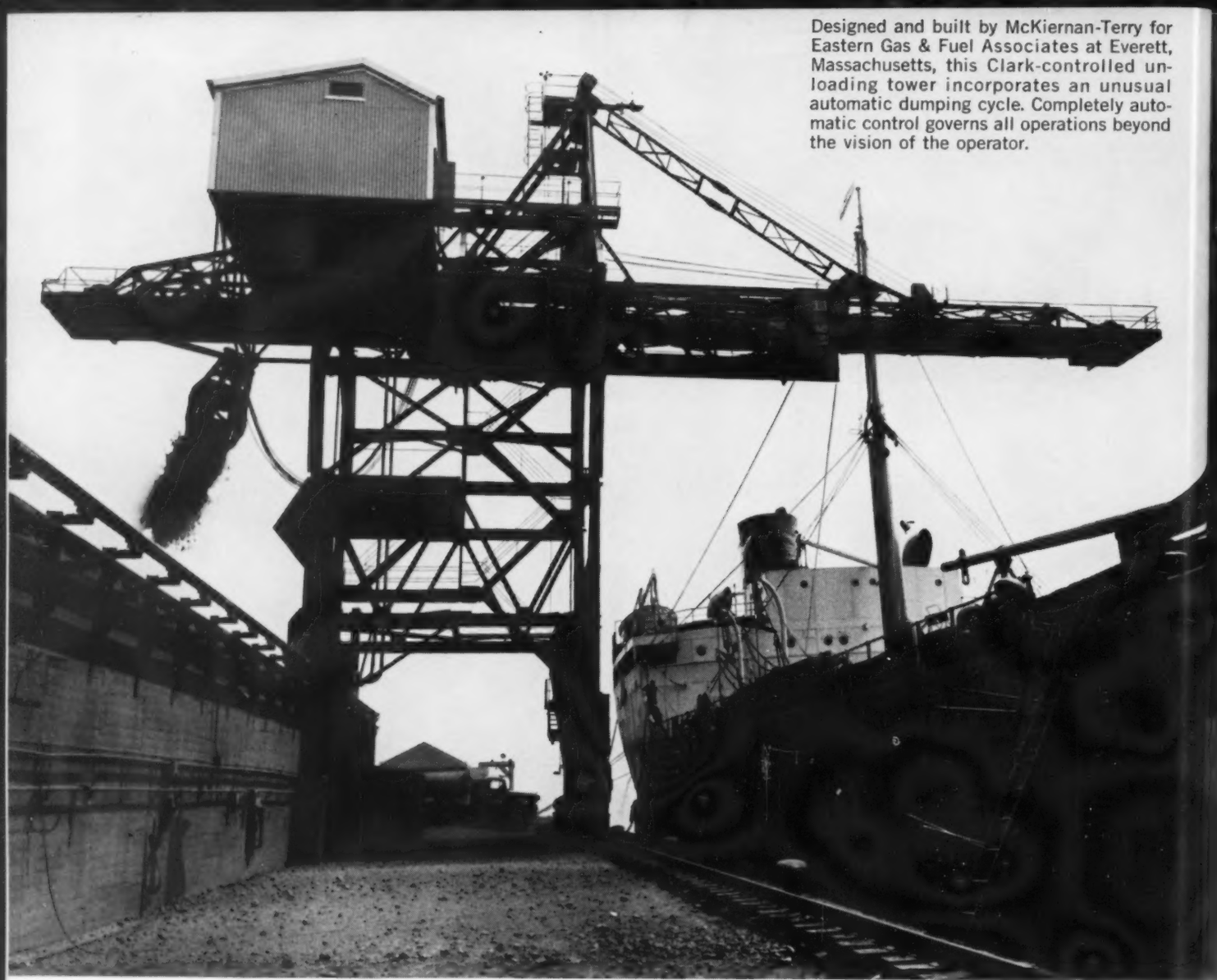
DREVER ENGINEERING FOR YOU

Your own requirements in industrial furnaces may be far afield from that shown here but you might want to consult with our engineers. Write or phone us. Drever Company, Bethayres, Pa. Wilson 7-3400.

DREVER INDUSTRIAL FURNACES

ENGINEERED TO YOUR PARTICULAR REQUIREMENTS

ENGINEERING AND MANUFACTURING FACILITIES AROUND THE WORLD THROUGH ASSOCIATES IN FRANCE, GREAT BRITAIN, GERMANY, ITALY, JAPAN AND INDIA



Designed and built by McKiernan-Terry for Eastern Gas & Fuel Associates at Everett, Massachusetts, this Clark-controlled unloading tower incorporates an unusual automatic dumping cycle. Completely automatic control governs all operations beyond the vision of the operator.

We gave a magic brain to this unloading tower

Building electrical controls to meet special requirements is a job for which Clark engineers are exceptionally well qualified. The Clark control system for this unloading tower, for example, features an automatic dumping cycle that is surer, smoother and faster than even the most skilled operator.

From his extendable cab overlooking the ship's hold, the operator fills the bucket and brings it up and back to the tower columns. The dumping cycle then becomes automatic and all motions are precisely controlled by Clark's unique "adjustable-in-motion" rotating cam limit switch. Trolley travel and bucket dumping are perfectly synchronized. The "plug" always is at the proper instant, followed by immediate return of the bucket to the front columns. Unloading becomes a continuous, flowing operation. A high free-digging rate is maintained with ease.

Working with men in industry to create equipment for better methods and greater economies is a job welcomed by our engineers. Just call the nearest Clark sales office or write: 61A1

THE CLARK CONTROLLER COMPANY

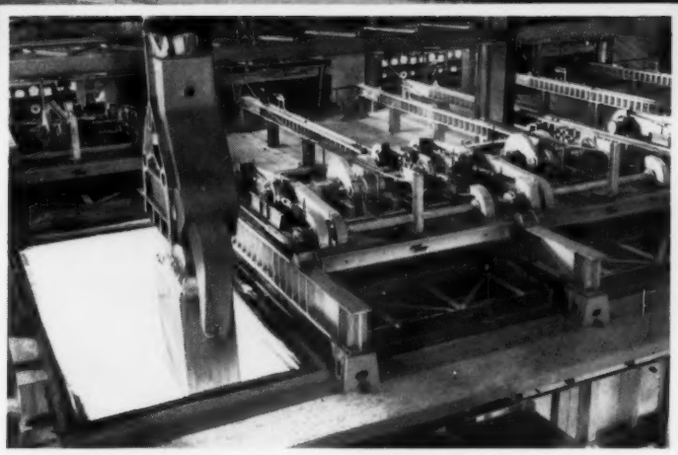
MAIN PLANT: CLEVELAND, 10 • **WESTERN PLANT:** LOS ANGELES, 58
IN CANADA: CANADIAN CONTROLLERS, LIMITED, TORONTO, ONT.

Salem-Brosius soaking pits at Inland Steel Co.

High production and low costs attract steel mill operators to Salem-Brosius soaking pits

All over the Free World — in United States, South America, Europe, Australia, South Africa, Japan and wherever steel is made — steel plant operators are specifying Salem-Brosius soaking pit furnaces. Salem-Brosius furnaces, with their rapid and uniform heating, easy operation, production economies, low maintenance cost, long life, and reduced metal loss, are helping these operators increase output, reduce cost, or both. There is quality in design, engineering, and construction of Salem-Brosius soaking pit furnaces.

A leader in the field of industrial furnace design and construction, Salem-Brosius, with its world-wide organization, is ready and able to help you solve any heating and heat treating problem. When you purchase Salem-Brosius furnaces, you are assuring yourself of maximum uniform production at minimum operating and maintenance costs. If your plans call for any type of metal heating or heat treating furnace, it will pay you now and for years to come to specify your furnaces to be built by Salem-Brosius.



Lukens Steel Co.'s battery of Salem-Brosius pits.

Soaking Pits by Salem-Brosius at Acme Steel Co.

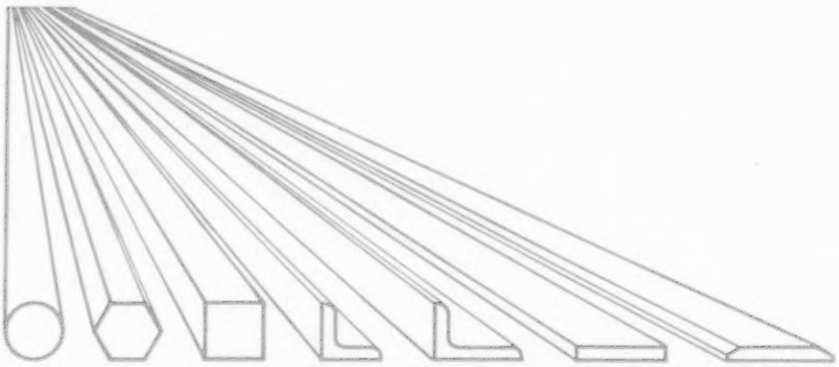
Salem-Brosius, Inc.

PITTSBURGH, PENNSYLVANIA

In U.S.A., South America, and Mexico—Salem-Brosius, Inc., Pittsburgh • In Canada—Salem-Brosius (Canada) Ltd., Rexdale, Ontario • In England—Salem-Brosius (England) Ltd., London and Milford, England • In Continental Europe—Salem-Brosius (France) S.A., Paris; and Ugnsbolaget, Svenska Metallverkens, Vasteras, Sweden • In Africa—Salem-Brosius, Inc., Pittsburgh; and Salem-Brosius (England) Ltd., London and Milford, England • In Australia—Head Wrightson (Australia) Pty. Ltd., Sydney, N.S.W. • In Japan and India—Daido Steel Co., Tokyo, Japan

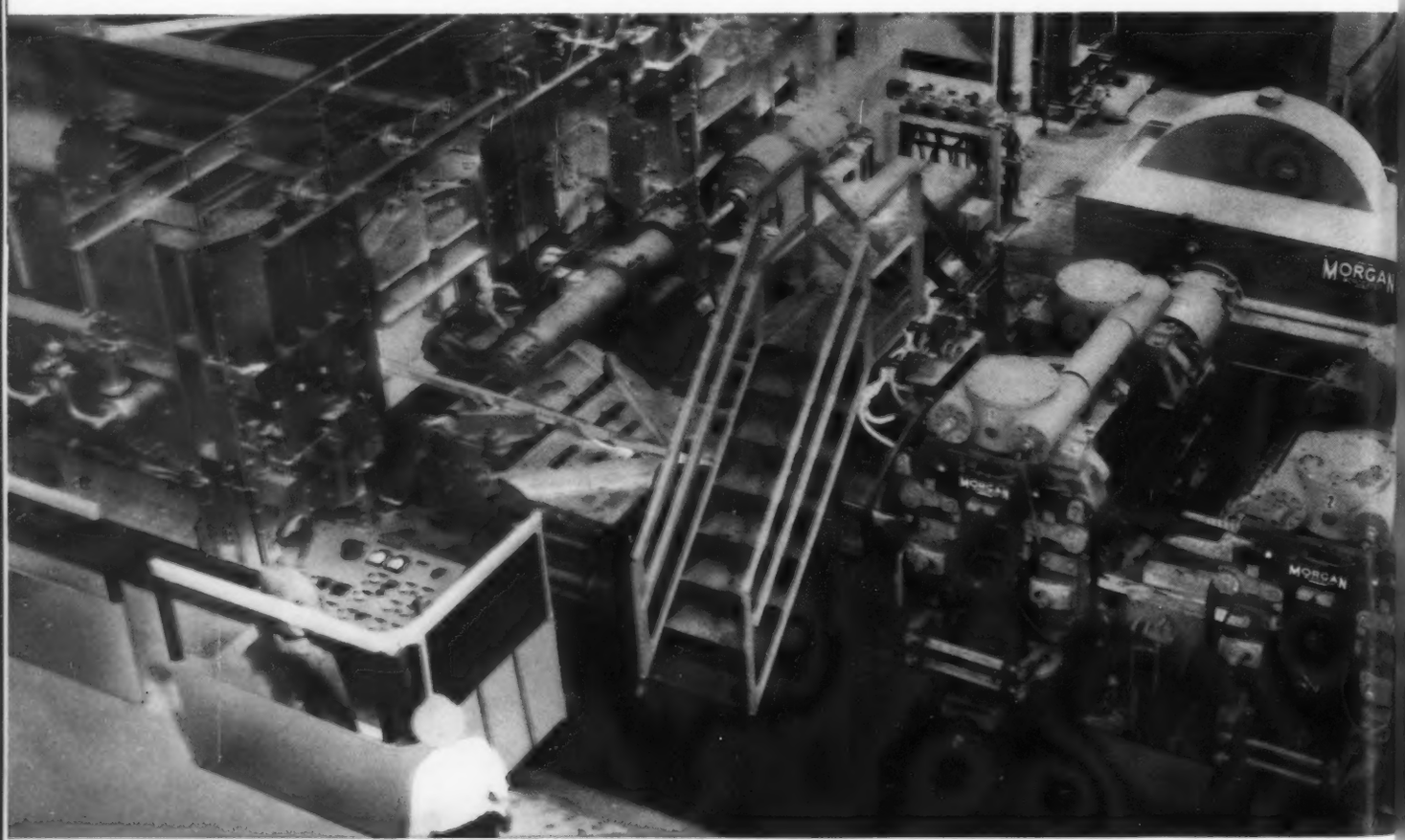
THE VERSATILE MILL WITH MARKETS IN MIND

Morgan Designed Mill for Sheffield has ability to Roll Wide Product Variety



ROUNDS • HEX'S • SQUARES • EQUAL ANGLES • UNEQUAL ANGLES • FLATS • BEVEL SKELP

Now rolling at three times previous production rate, the Morgan-built No. 2 rod mill in the Kansas City plant of Armco Steel Corporation's Sheffield Division was designed to turn out with equal efficiency any shape in the broad range of product demanded by current market trends. This example of Morgan creative engineering has gained world-wide recognition as the fastest 10″, 3-strand rod mill—proving again the operating benefits inherent in Morgan know-how and capabilities, accumulated in over 70 years of rolling mill pioneering.



MORGAN WORCESTER

MORGAN CONSTRUCTION CO.

WORCESTER, MASSACHUSETTS

ROLLING MILLS • MORGOIL BEARINGS • WIRE DRAWING MACHINES • COMBUSTION CONTROLS

You get more value for the same dollar— in the NEW Bulletin 709 line of starters!

SIZE 00

SIZE 5

This new line of Allen-Bradley motor control will change every idea you have had about starter size, performance, and life. The small size—especially in the higher ratings—is startling. Yet rating for rating the operating life and reliability have been increased many times. Built into each of the seven sizes of this new Allen-Bradley line is an ability to interrupt tremendous currents and to operate year in and year out for many millions of operations without trouble or maintenance.

The new Bulletin 709 starters are just as advanced in appearance as they are in performance. All seven sizes have an aristocratic styling and a distinctive family likeness. Brooks Stevens, famous industrial designer, has given the enclosures such an attractive, modern style that these new starters will prove a distinct sales asset on any machine or installation.

Why not write today for more information on this revolutionary new line of Allen-Bradley Bulletin 709 *quality* across-the-line motor starters?

Note the compactness of both the smallest and largest starter in the new Bulletin 709 line. Ratings up to 100 hp, 220 v; 200 hp, 440-550 v.

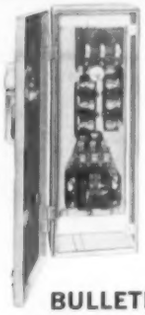
12-61-RM

ALLEN-BRADLEY

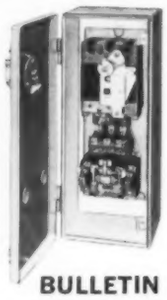
Member of NEMA

Allen-Bradley Co., 1316 S. Second St., Milwaukee 4, Wis.

QUALITY MOTOR CONTROL

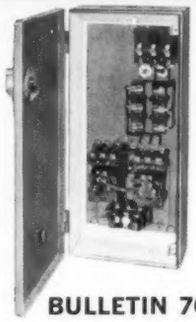


BULLETIN 712
Size 1 combination starter with fused disconnect switch



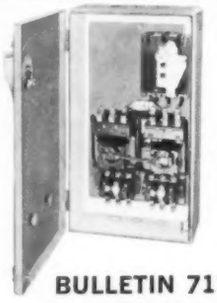
BULLETIN 713
Size 1 combination starter with circuit breaker

BULLETIN 705
Size 2 across-the-line reversing starter with overload relays

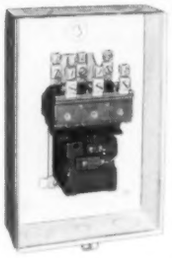


BULLETIN 706
Size 1 reversing starter with fused disconnect switch

BULLETIN 715
Size 1 across-the-line, multi-speed starter with overload relays



BULLETIN 717
Size 2 multi-speed starter with circuit breaker



BULLETIN 702
Size 3 three-pole, a-c solenoid contactor

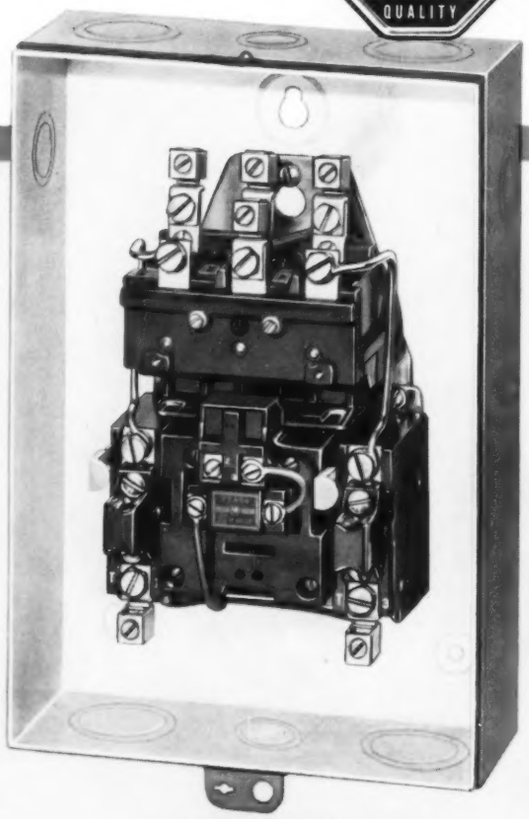
A-B QUALITY

Pygmies in Size
Giants in Performance—
the NEW Allen-Bradley Across-the-Line Starters!

This new line of across-the-line motor starters is the result of over 30 years of experience and leadership in the motor control field.

While retaining the simple solenoid principle—with only ONE moving part—these starters are completely new in every way. They are amazingly small in size—yet test after test has proved they will not only outperform but also outlast any starter now on the market. They are good for *many millions* of trouble free operations. All have scores of design refinements that make them easier to install and maintain. All are available in the smart new enclosures designed by Brooks Stevens. They make a beautiful addition to any machine or control installation.

You'll want to get the complete story about these truly revolutionary new across-the-line starters. Write for new Publication 6100.



BULLETIN 709

This popular across-the-line solenoid starter shows the new Size 2 construction. Note the white interior and generous wiring space. Bulletin 709 starters are available, in the new construction, in seven sizes—Sizes 00 to 5, with a maximum rating of 100 hp, 220 v; 200 hp, 440-550 v.

12-61-RM

ALLEN-BRADLEY

Member of NEMA

Allen-Bradley Co., 1316 S. Second St., Milwaukee 4, Wis.

QUALITY MOTOR CONTROL

HOW FAR . . . AND HOW FAST . . .

can you use computer control *profitably?*

BAILEY 700 SYSTEMS can help you determine—one step at a time

Can computer control be used—profitably—in your steelmaking operations?

Where and how?

The answer often lies in intermediate stages of improvement in sensing, measuring, controlling, computing.

Measurements now being obtained may be insufficient, or they may be profuse. Analysis, evaluation, simplification can provide substantial improvements to the point of profitable investment return.

Bailey engineers can help you determine and prove — one step at a time — how far analog or digital systems or control can be profitably applied in your operations. Bailey is equipped, by broad experience, to provide single-source responsibility from sensing and measuring instrumentation to complete automatic control. *Bailey 700 Systems* are installed, in operation, or on order, at locations from coast to coast.

Find out what this Bailey background in instruments and control can offer you. Contact your Bailey District Office.

Where Bailey progressive automation and Bailey 700 Systems aid steelmaking operations

SINTERING—to achieve maximum quantity and quality of output at lowest cost.

BLAST FURNACES — to provide lower coke rates and higher yields.

OPEN HEARTH—to increase production and control delays.

OXYGEN CONVERTERS—to maintain product quality at highest production rates.

PLANT UTILITIES—to reduce power and fuel consumption while still meeting plant requirements.

S121-1

IRON AND STEEL DIVISION

BAILEY METER COMPANY

1047 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

BAILEY METERS

How NBD product engineering produces better screw nuts

A report on centrifugally cast screw nuts and a new proof-ring inspection method

What makes a good screw-down nut? How long should it last? What causes early failure? When NBD product engineers were assigned the job of producing superior screw-down nuts, they asked these questions of blooming and slabbing mill operators. Answers varied greatly. "Good" life in one mill might be 1,000,000 tons of steel rolled. In another, life might be 4,000,000 tons — because of the peculiar operating characteristics of the mill. All agreed, however, that NBD's greatest contribution would be: (1) Production of screw nuts having maximum physical properties within the limits of the bronze alloy specified, and (2) absolutely sound castings, particularly in the critical threaded areas of the nut.

Evaluation method

Because of the recognized superiority of centrifugal castings for most applicable bronze designs, this method of manufacture seemed the logical approach to attain the desired screw-nut characteristics. Questions were

raised, however, in connection with the heavy metal sections of screw nuts, often exceeding 6". Would the mass effect of these heavy sections promote shrinkage or massive grain growth which would adversely affect tensile properties?

To resolve the questions, NBD product engineers made comparative tests on two 6,000-pound nuts, poured under identical controlled conditions from the same heat of NBD Alloy 65 N. (87½% Cu—11% Sn—1½% Ni). One was cast centrifugally. The other was cast in a chilled static mold.

Duplicate test sections were then cut from each casting, diametrically opposite each other, from several locations in the nuts.

TENSILE TEST RESULTS

Test Location	Tensile Strength, PSI		Yield Strength, PSI		% Elongation—2"	
	Centrifugal	Static	Centrifugal	Static	Centrifugal	Static
A	54,800	52,800	26,700	23,700	37.0	31.25
B	53,325	52,200	26,850	23,950	30.25	34.5
C	51,800	46,600	26,750	23,900	22.0	23.0
AVERAGE	53,308	50,533	26,767	23,850	29.75	29.58

HARDNESS READINGS

Hardness readings were also made on slices cut from the nuts, near the top, center and bottom. These readings, taken at 1" intervals from the O. D. to the I. D. were as follows:

BHN Hardness—500 kg Load

	O. D.	1"	2"	3"	4"	5"	6"	I. D.	Average
Centrifugal	98.5	99.0	94.5	96.5	98.0	99.5	95.0	97.0	97.25
Static	100.0	99.0	97.0	96.0	92.5	87.0	88.0	90.5	93.75

Micro and Macro Studies

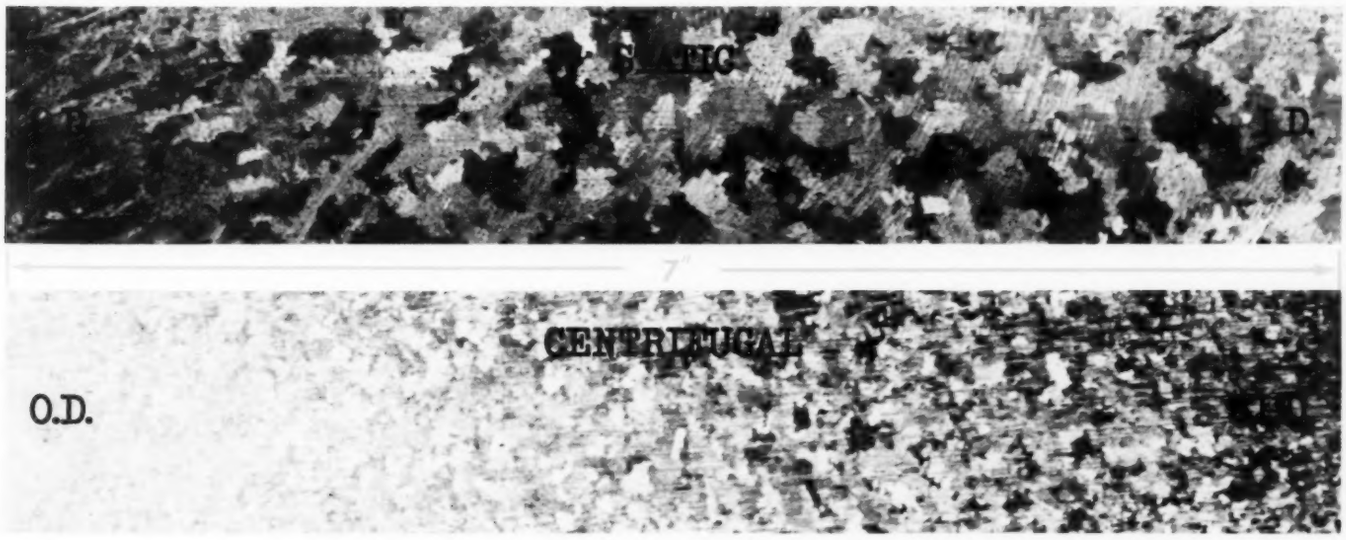
Micro and macro studies further strengthened the case for centrifugal castings, particularly in the critical I. D. of the screw nut. Note the pronounced finer grain in the centrifugal macrophotograph.

Proof-ring assures 100% quality

While the foregoing tests proved the superiority of the centrifugally cast nut — one big question remained: How could NBD customers be absolutely positive that every screw nut purchased was dense, sound and strong in the important threaded area? Visual inspection was not the answer. Dye-check, used extensively by NBD, was only partially effective. X-Ray was not practical because of the heavy metal sections involved.

From this enigma came a unique solution: a proof-ring which *exactly* duplicates the quality of the thread area of the casting. Without damaging the nut in any way, the proof-ring may be chemically analyzed, fractured, studied microscopically or otherwise tested. The proof-ring can be shipped to customers for evaluation — enabling them to inspect the nut quality — prior to its shipment.

The NBD sales engineer is prepared to give you more details on this proof-ring testing method. For further details on this unique proof-ring inspection technique, contact an NBD sales engineer, or write us.



AMERICAN Brake Shoe COMPANY

NATIONAL BEARING DIVISION
717-L Grant Building • Pittsburgh 19, Pennsylvania
PLANTS IN: ST. LOUIS, MO. • MEADVILLE, PENNA.

THIS IS AN AAF AIR FILTER*

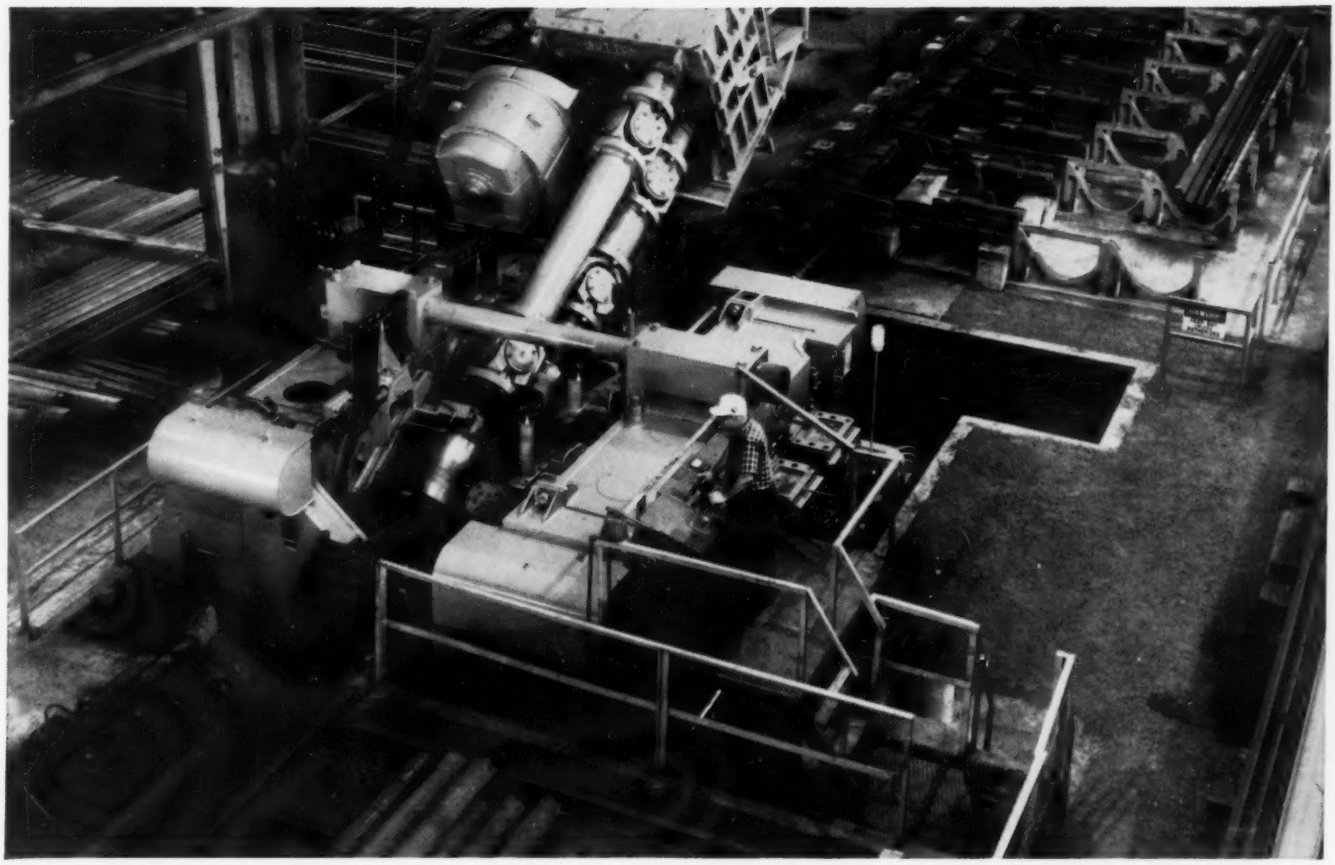
that can never get to COLUMBIA-GENEVA'S electrical equipment

Dust and dirt—the arch enemies of steel mill electrical equipment—don't have a chance at U. S. Steel's new Columbia-Geneva Division Mill at Geneva, Utah. AAF was called on to make sure of that.

Six different types of filters were required to handle all the clean-air needs at Columbia-Geneva. AAF is uniquely able to meet *all* air-cleaning needs because only AAF makes *all* kinds of air filters. Ask your local AAF representative for Bulletin 518 or write us direct. Address: Mr. Robert Moore, American Air Filter Company, Inc., 302 Central Avenue, Louisville, Kentucky.

*AAF Roll-O-Matic renewable-media air filter.

AAF American Air Filter
BETTER AIR IS OUR BUSINESS



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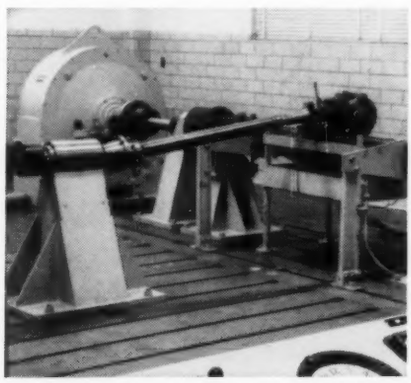
ON-THE-SPOT engineering service from our graduate-engineer salesmen solves bearing problems. They can help you select the one bearing from thousands that is exactly right for each position.



RESEARCH AND DEVELOPMENT, typified by the dynamometer above help keep Timken bearings your No. 1 bearing value. The data it provides helps increase performance of Timken bearings.

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The Timken Roller Bearing Company, Canton 6, Ohio. Cable: "TIMROSCO". Makers of Tapered Roller Bearings, Fine Alloy Steel and Removable Rock Bits. Canadian Division: Canadian Timken, St. Thomas, Ont.

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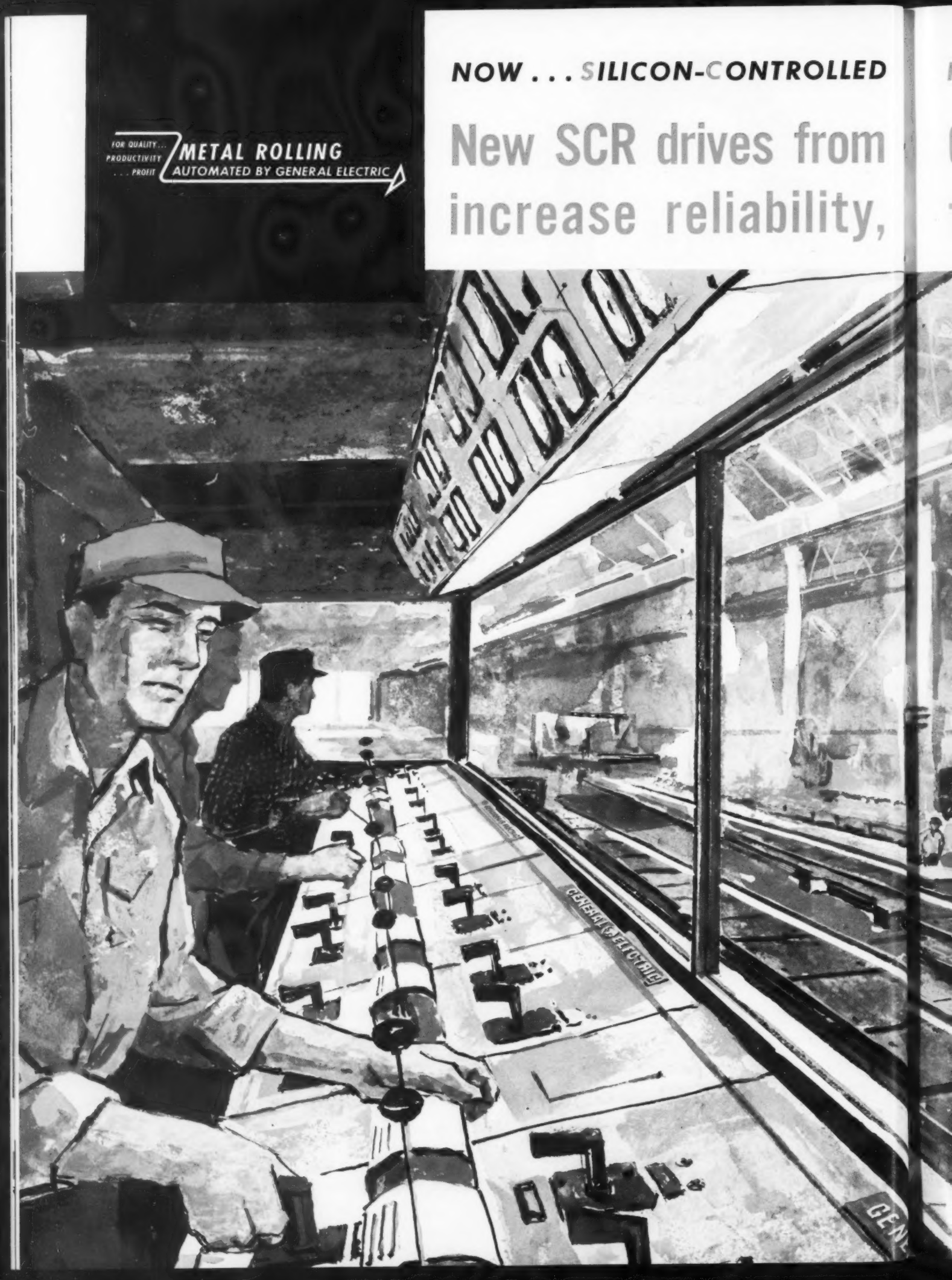
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New SCR drives from
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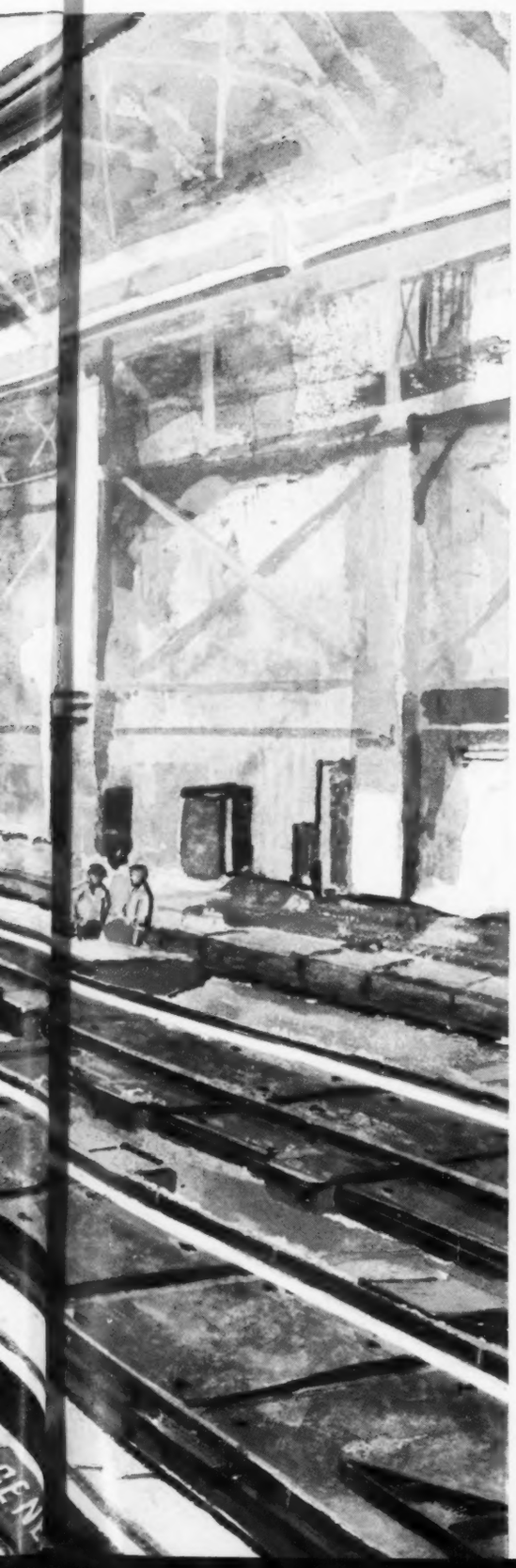
General Electric reduce maintenance, take up to 50 percent less floor space



General Electric now offers steel mill drive systems for field excitation and armature supply featuring the reliability and fast response of silicon-controlled rectifiers. More than two years of successful application of SCR's by General Electric in varied industrial situations has proved their long life and high efficiency in mill conditions: SCR's are unaffected by dust, moisture, shock, or vibration. Look at these cost-cutting and profit-producing benefits:

Higher reliability—SCR's are solid-state semi-conductors with no tubes, relays, or other moving parts. SCR's have longer operating life, so downtime for maintenance is significantly cut.

Reduced floor space—up to 50 percent less than previously required for drive systems . . . space can be made available for other purposes or construction costs can be cut on new buildings.

Quicker response—to signal deviation provides more accurate speed control. SCR's require no warmup before operation.

The application of silicon-controlled rectifier drives in steel mills is another example of how General Electric has served the steel industry for 75 years with products and systems to help make steelmaking faster, more efficient, and more profitable. Your General Electric sales representative is ready to assist you in planning for automation in existing facilities or in new mills . . . not only with systems using SCR's but with complete electrical systems for all process controls. Or, for additional information on SCR systems, write Section 785-16, General Electric Co., Schenectady, N. Y.

Industry Control Department, Salem, Virginia

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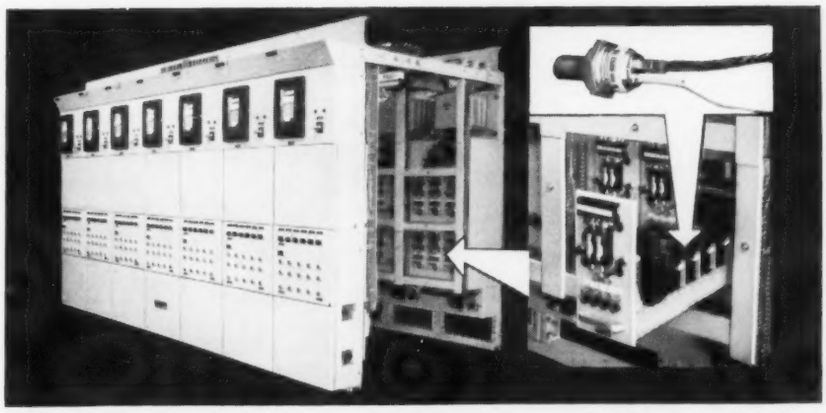

COMPACTNESS of G-E silicon-controlled rectifiers permits complete panel assembly and testing before shipment. Field installation and maintenance is facilitated because like functions can be grouped, faults quickly located.

MILL-DUTY ACCESSORIES

MASTER SWITCHES

Heavy-duty design offers long life, high reliability

Self-lubricating phenolic cams—impregnated with graphite—keep General Electric master switches performing longer . . . even in the toughest conditions. Numerous mill installations show that these cams—coupled with steel cam followers—will operate millions of times without replacement.

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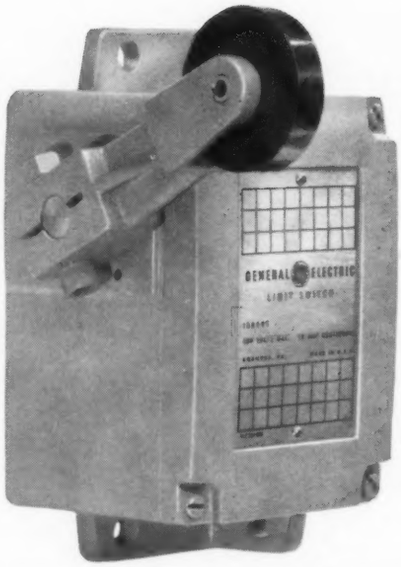
- **Pawl arrangement** allows for convenient adjustment to each operator's "feel."
- **Adjustable stops** give maximum of seven points in each direction, plus off.

Want more information? See your G-E Sales Engineer; or write Sect. 784-28, General Electric Co., Schenectady, N. Y. for Bulletin GEA-6706. *Industry Control Dept., Salem, Va.*



LEVER LIMIT SWITCHES

New adjustable cams permit fast, on-the-job adaptation

Here is a new lever-operated limit switch that lets you adapt it to the application . . . right on the job. You no longer need to predetermine circuit requirements before selecting a device. This means fast installation or quick adaptation when requirements change. A new system of adjustable cams on General Electric's lever limit switch makes this flexibility possible. A template—provided with every switch—guides changing the cams.

Lighter and more compact, General Electric limit switches are available for either two- or four-circuit operation . . . and, in a wide choice of enclosures.

Consider these key features of the new General Electric lever limit switch:

- **Readily-accessible contact blocks** are of unit construction, easy to wire.
- **Variety of levers** offers wide selection to meet your specific application.
- **Starwheel** may be set for either maintained or spring-return operation.

For the complete story, see your General Electric Apparatus Sales Engineer, or write Section 784-28, Schenectady, N. Y. for Bulletin GEA-7203. *Industry Control Dept., Salem, Virginia.*

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For example, failure of a water line at an eastern steel plant in 1946 prompted this producer to turn to TAPECOAT for protecting the new line. Results were so conclusive that they have since standardized on TAPECOAT for wrapping fire prevention, water, gas and fuel lines in sizes ranging from 2″ to 48″.

TAPECOAT comes in rolls of 2″, 3″, 4″, 6″, 18″ and 24″ widths. It is easy to apply with the use of a torch. No skilled help required.

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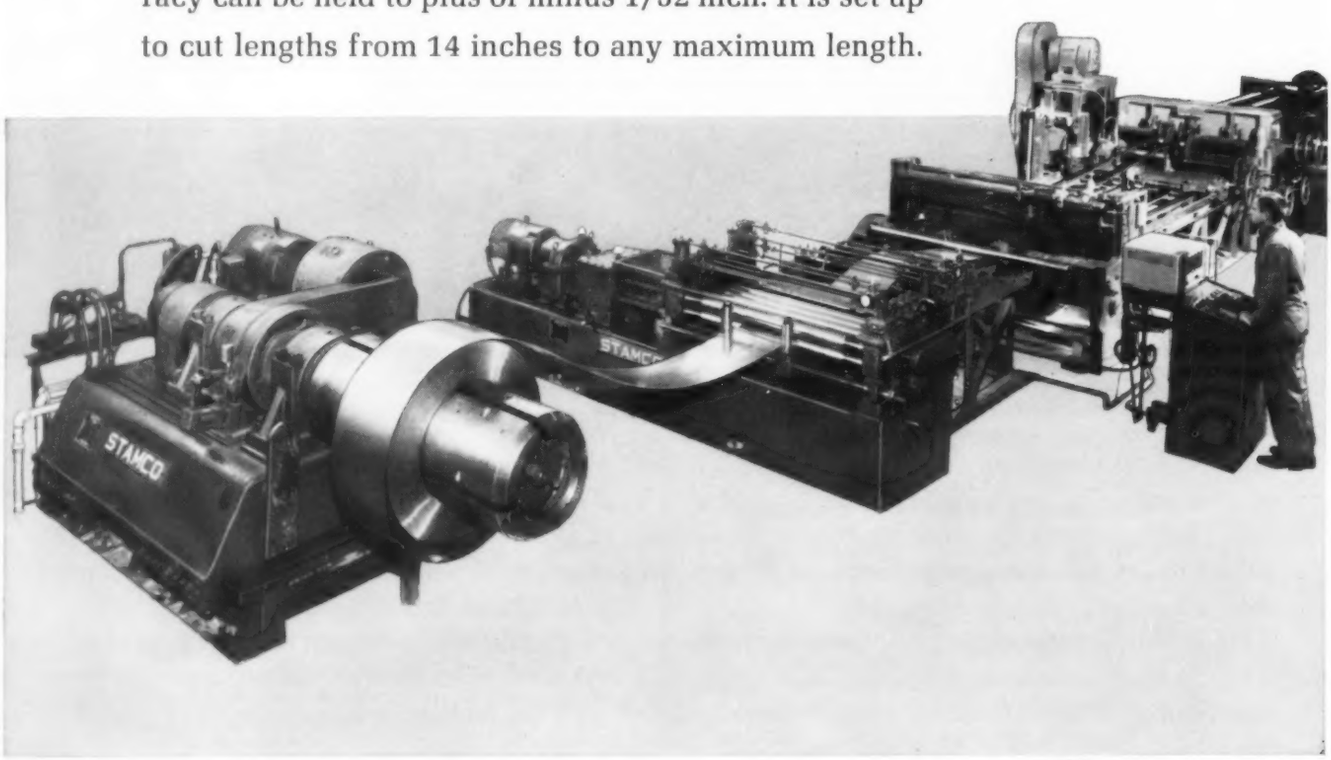

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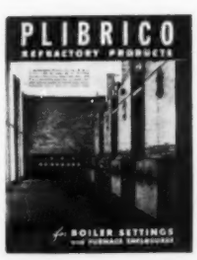

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Now available in latest improved design, Eberhardt tuyeres have a forged nose of certified OFHC® copper with at least 98% IACS conductivity, and a cast body of virgin electrolytic copper guaranteed at least 90% IACS conductivity. Replaceable nose permits re-use of 80% of tuyere copper. Exclusive design provides maximum heat transfer and efficient cooling of the nose section.

Write or call today for your trial order. Start saving 20 to 34% of your tuyere cost per day!

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*U.S. Patent No. 2,891,783—Bethlehem Steel Company.
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The reason: **MORGOIL** bearings are products of many years' experience in the rolling mill field featuring sound design, precision manufacture by skilled craftsmen and continuing research—all backed by an alert field service organization.

Write for technical counsel on any application.

M-2

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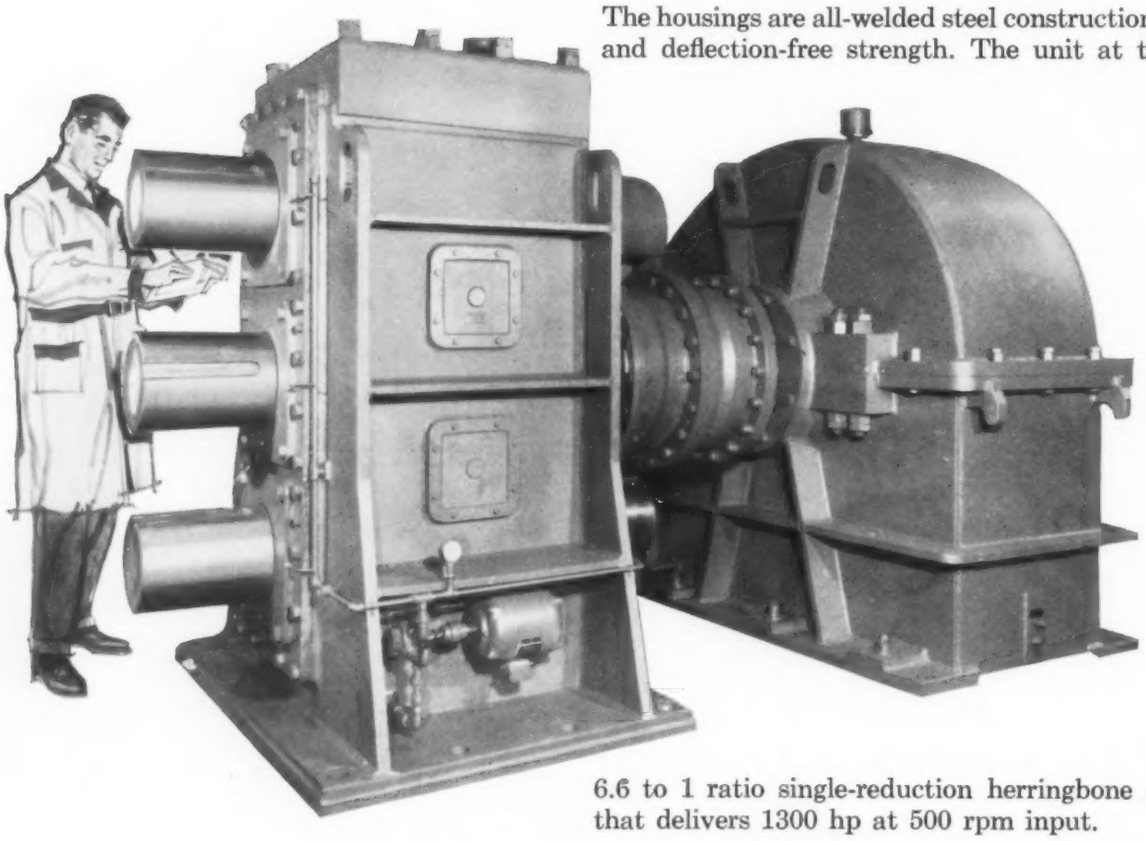
D. O. James all-welded heavy-duty steel mill drives

This two-high rolling mill drive is typical of D. O. James' capabilities in heavy-duty reducers and gearing.

The housings are all-welded steel construction for economy and deflection-free strength. The unit at the right is a



6.6 to 1 ratio single-reduction herringbone gear reducer that delivers 1300 hp at 500 rpm input.

The reducer is coupled to a pinion stand having three pinions with 23″ between vertical centers. Pinion ratio is 1 to 1. Horsepower is 825 at 86 rpm input.

When you require heavy-duty, high-efficiency drives, call your local D. O. James representative or write to the factory. You'll be glad you did.

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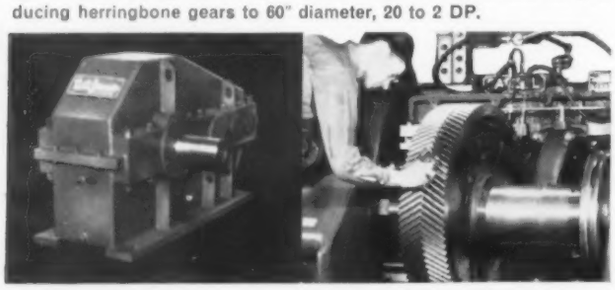
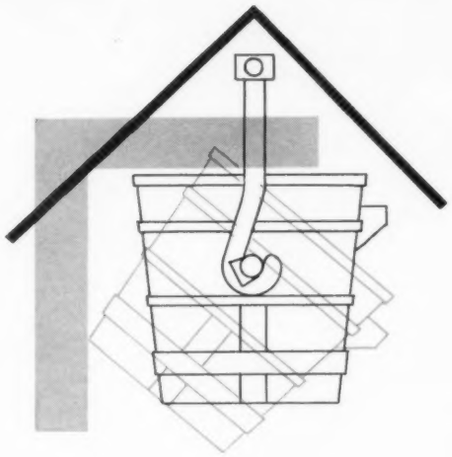
Below left — D. O. JAMES triple-reduction herringbone reducer with all-welded housing. *Below right* — D. O. James has facilities for producing herringbone gears to 60" diameter, 20 to 2 DP.



D.O.James

...where you always get good gearing



STEEL ANGLES

ONE of the principal objectives of the steel industry, and every other industry in the American economy, has been the achievement of continually increasing productivity. No one questions the desirability of this goal for its attainment has profited labor, management and the general public. Further, a true increase in productivity represents an increase in our real wealth, for productivity, strictly speaking, is a ratio between the input factors of production, viz., labor, raw materials, capital equipment and the output or product. Whenever the ratio improves it means we are getting a greater return on our investment of time, money and materials.

In examining the causes for advancing productivity in the steel industry we find the principal one by far is improved machinery for capital equipment. Developments in technology have been responsible for the really great advances, as was the case in the light flat rolled segment of the industry when the wide strip mill and the cold reduction process were developed and generally installed in the late 1920's and 1930's. The output from a 10-stand continuous hot strip mill with a crew of 35 men is so much greater than that from four to five hand sheet mills employing the same number of men that the comparison is staggering. However, the investment in the hot strip mill is also staggering in comparison to that involved in four or five hand sheet mills.

The strip mills and cold reduction mills installed in the depression days of the 1930's were not an unmixed blessing, for they displaced a sizable group of men and thus added to the number of unemployed. In fact, the problem reached such proportions that it became part of a congressional investigation. Yet, in spite of the difficulties that were faced at that time, no one felt that we should abandon the new process and return to the antiquated, obsolete hand mill.

The strip mill represented progress and made possible a tremendous increase in the quantity and quality of the steel produced. Were it not for this development, we could never have had the economic growth and the increase in standard of living of the past twenty years, for the old methods could never have satisfied the demands of the present-day economy. Further, in terms of total employment in the steel industry, we find that in the long run, i.e., 10 to 15 years later, it actually increased.

It would appear then that this major technological development, so significant in increasing productivity, resulted in severe short run dislocations, principally because it was introduced during a depression. However, in the long run it proved to be a benefit for all concerned. Had the same change taken place in the late 1940's and early 1950's, it would have been completely welcome, for at that time the steel industry enjoyed a period of growth and record activity, as did most of the economy, and the displaced workers could have been very easily absorbed in the steel industry itself, or elsewhere.

Since the close of World War II there has been a constant series of technological changes in steel. Some, such as the extensive use of oxygen in steelmaking, have been spectacular, while others have been of relatively minor significance. Nevertheless, all have contributed to increased efficiency and increased productivity, and in some instances, manpower has been eliminated. Fortunately, there have been no wholesale layoffs to compare with those experienced as a result of the introduction of the strip mill. Because of the rather high level operation, most men displaced in one job could be absorbed in another, and indeed there was relatively little said about technological unemployment until 1958, a recession year, and also the latter part of 1960, when the steel operating rate dropped to about 50 per cent. With layoffs running into the thousands, there was much talk of technology or structural unemployment. Yet in the steel industry, one can determine very readily from an examination of the facts that the layoffs were due principally to low operating activity and only to a minor extent to the introduction of new equipment.

During a period of economic recession, it is understandable that there will be a certain amount of resentment and opposition to technological change among those who are affected. Most industries in the past five or ten years have taken steps to mitigate the impact of such change, either by providing generous financial adjustments or training programs to relocate the displaced employees. An agreement between the Pacific Maritime Association and the International Longshoremen's and Warehousemen's Union has resulted in the creation of a stabilization fund based on the savings from technological change. Its purpose is to insure employees against the loss of work due to technological change. Employees are assured that available work will be shared equally by them, and that the work force will decline only as a result of normal attrition.

The installation of more efficient and productive machinery is not only healthy, but necessary. It will enable us to provide more goods and services for more people and thus increase the standard of living. It will enable us to face competition from abroad, where wage rates are lower, with a greater degree of success, and although there will be temporary dislocations in employment, it will prevent obsolescence from overtaking the industries in our economy. It is precisely here that we will be able to maintain employment, for in spite of the fact that a modern plant may use less workers, an obsolete plant is doomed to extinction with the consequent loss of jobs for all of its workers. We have but to look at the history of some European industries to verify this fact. ▲

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Fast top charging, accurate control, rapid melting—all combine in a Lectromelt furnace to give high availability. Lectromelt furnaces have the ability to take it, while also maintaining high quality, when you pour on the power to get top production. Catalog 10-A describes these furnaces in detail. For a copy, write Lectromelt Furnace Division, McGraw-Edison Company, 310 32nd St., Pittsburgh 30, Pennsylvania.

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Conventional Batch Annealing

by GEROME GORDON, Vice President, Swindell-Dressler Corp., Pittsburgh, Pa.

. . . . productivity and thermal efficiency of conventional batch annealing has increased greatly since World War II and continuing research promises to further improve the process. . . .

CONVENTIONAL batch annealing should be discussed from the aspects of:

1. Investment cost per ton.
2. Production capacity.
3. Quality of product.

Since World War II there has been a tremendous increase in the volume of flat rolled products requiring annealing as part of the processing, thereby giving incentive to the industrial heating industry, working closely with the steel producers, to advance the art and techniques of annealing as well as to improve the design of processing equipment to a degree far beyond what had been realized in any similar period prior to the war.

As a method batch annealing has participated fully in this progress. Prior to the war, most sheet and tin plate was annealed in the form of cut sheets in inefficient direct-fired, stationary in-and-out batch type furnaces, requiring extremely long heating cycles, and leaving much to be desired in respect to quality.

In the few years just prior to the war, portable rectangular hood type furnaces were introduced along with indirect gas-fired radiant tube heating. Still relatively long heating and cooling cycles were required, since the heavy stacks of cut sheets inside the protective innercovers relied for heat transfer almost entirely on radiation between the edge of the sheets and the innercovers. Nor from the viewpoint of productivity was there any improvement when coiled strip steel was later

Figure 1 — Each furnace base is capable of accepting four stacks of 72-in. OD coils up to 166-in. high.

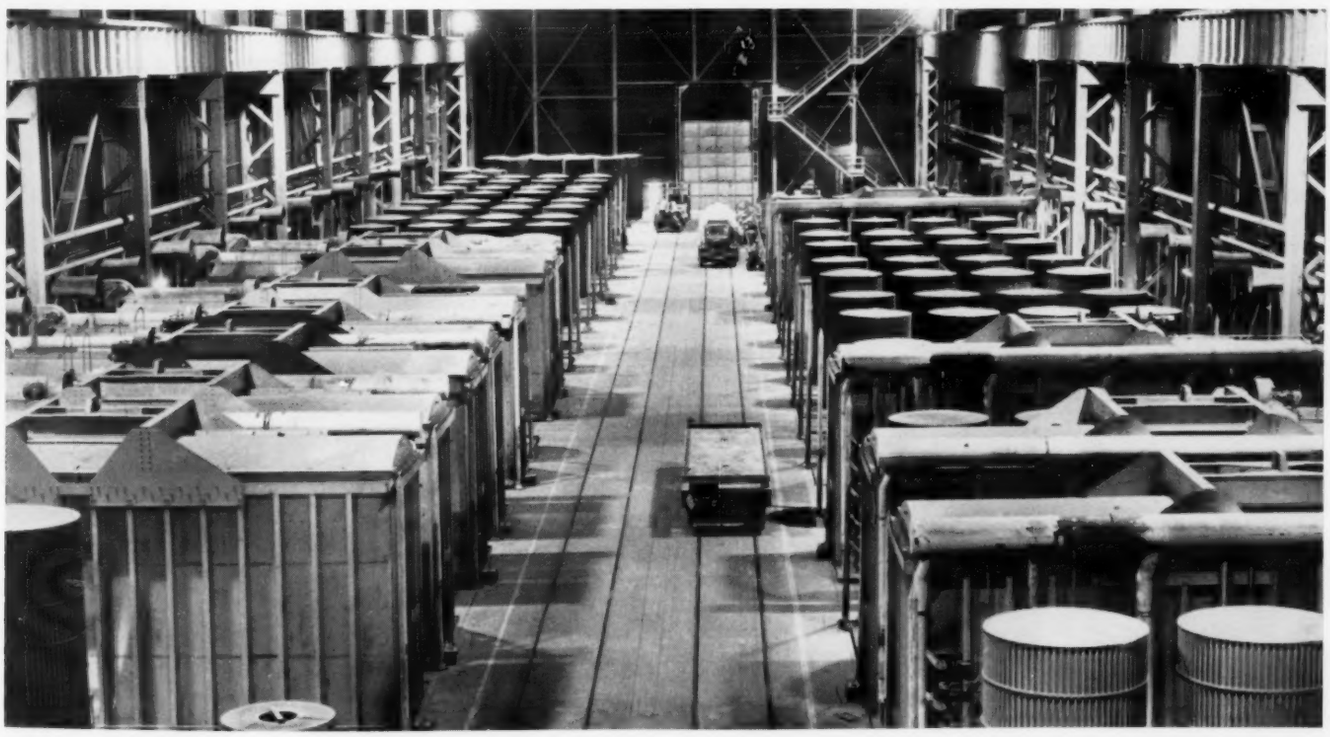


Figure 2—Single-stack annealing furnaces are often used in processing small orders of special alloys.

charged into these same types of furnaces, since there was still no provision for forced circulation of atmosphere gas within the inner-covers.

It was not until peacetime economy returned that furnaces designed specifically for annealing strip steel in coil form were introduced in quantity. These furnaces provided for vertical stacking of several coils on circular pedestals, each under individual cylindrical inner-covers, either individually or in multiple stacks on a common rectangular furnace base. Each pedestal was provided with a small propeller type fan driven by a ·1 to 3-hp vertical motor for the purpose of circulating atmosphere gas in order to transfer some heat from the inside of the inner-cover to the core of the stack of coils by forced convection.

During the intervening years from the second world war up to the present time, productivity and thermal efficiency of portable hood type batch annealing furnaces have increased greatly, while achieving much better strip steel quality by improved control of temperature uniformity and atmosphere gas during the annealing operation. Contributing to over-all process improvement have been such factors as:

1. More efficient and high volume atmosphere gas circulating fan systems coupled with the use of convector separator plates between coils and corrugated stainless steel inner-covers.
2. Methods for avoiding air infiltration within the atmosphere gas recirculating system coupled with the generation of better gas atmospheres.
3. Greatly improved combustion systems, including improved radiant tube design, manufacturing and application techniques.

Consequently, the position of batch annealing today remains paramount in spite of the recent introduction of other processes, for the following reasons:

Flexibility—The batch type operation is suitable for processing a wide variety of product in relatively small lots. Consequently, superior customer service may result in many cases as well as a high degree of over-all versatility.

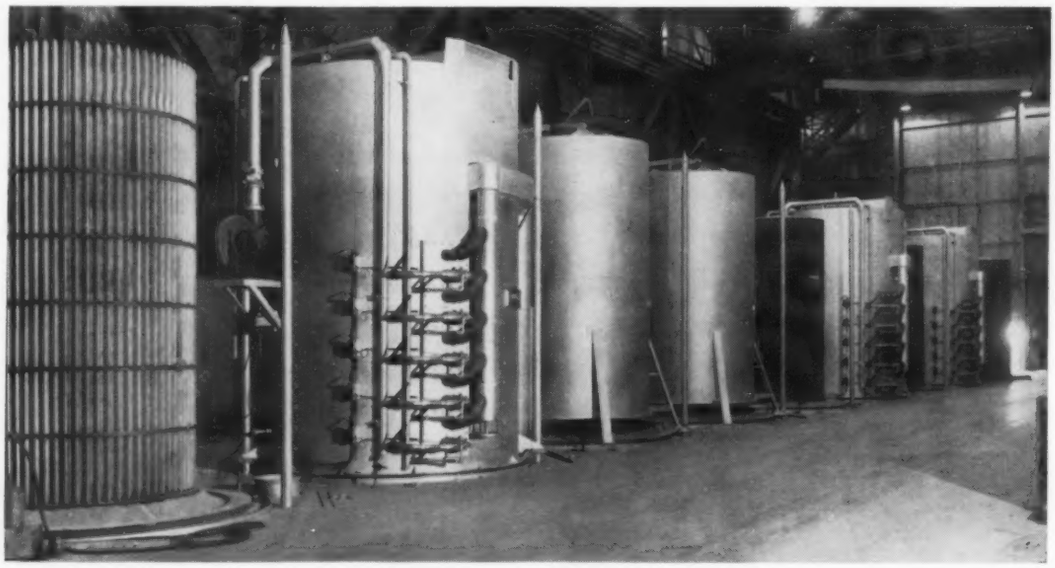
Quality—Inasmuch as the process readily permits a wide variety of heating cycles to be employed, temperature and soaking time can be easily varied, as, for example, in the production of high-grade drawing quality automobile sheet and tin plate as well as economical production of commercial quality sheet.

Economy of Operation—By virtue of its extreme simplicity and high efficiency the batch annealing process is low in fuel consumption (usually less than 1,000,000 Btu per ton annealed), is low in electrical power consumption (requiring little more than the power used to circulate atmosphere gas and to drive combustion air blowers), uses no plant water and requires little attention per ton annealed (by either operating or maintenance personnel). The total cost above for batch annealing, considering all of these factors (including repair and maintenance costs), varies from plant to plant in the range of $1.40 to $2.00 per ton, depending on plant capacity, level of production, product split, etc.

Initial investment cost per ton—Considering a modern installation of 4-stack hood type furnaces, to process 50 per cent deep drawing quality sheet and tin plate and 50 per cent commercial quality sheet in 72-in. maximum OD coils, for an average productivity of five tons per hr, the cost per ton of the installed annealing equipment only, would be about 25¢ per ton over a 20-year period.

Further efforts are being made to improve batch annealing equipment, since it appears quite likely that the special advantages of this method of treating the great bulk of steel strip will continue to be significant in the foreseeable future. ▲

Figure 3—Corrugated alloy inner-covers have increased the radiation heating effect, rapid-cooling hoods have decreased process time.



Use of Open Coil Process to Change Composition and Improve Sheet Steels

. . . . open coil annealing with various gas compositions allows control and change of steel analyses during the annealing process, thus opening the possibilities of making lower cost steel products. . . .

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IT is common practice in the steel industry to anneal sheet and tin-plate products by box annealing, by continuous annealing and by continuous or cut-length sheet normalizing. The purposes of the annealing are to prepare the steel for further processing in the steel mill and to develop the combination of properties required of the steel for successful application by the customer.

Box annealing is still the most widely used method for annealing flat-rolled steel products. Practices and equipment are well developed, and annealing costs are low in comparison with those of the other methods. However, box annealing has some serious disadvantages. First, because all the heat must be transmitted through the small outer-surface area of the coil into the large mass of the coil, the annealing cycles are long and the properties of the product may vary due to temperature differences in the charge. Second, because the steel "stews in its own juice," so to speak, the surface characteristics of the product may be poorer than desired.

The use of continuous annealing has grown tremendously in the past 15 years, particularly for the production of tin plate, electrical sheets and galvanized sheets. In continuous annealing the heating and cooling rates are very rapid and the entire surface of the steel is exposed to the controlled annealing atmosphere. Normalizing, such as is done in the processing of low-metalloid enameling steel, differs importantly from continuous annealing only in that higher temperatures are used and the atmosphere may be air instead of a protective gas. Because the time at temperature during continuous annealing is very short, however, it is not possible to produce steel as soft as can be produced by box annealing. Furthermore, even though all the steel surface is exposed to the annealing atmosphere so that gas-metal reactions such as decarburization can occur, they can proceed only to the extent that the very short continuous-annealing times will permit.

At the 1958 Annual AISE convention, Lee Wilson described a newly developed annealing method for sheet and tin plate called "open coil annealing" that seemed to combine the best features of conventional box and continuous annealing without their inherent disadvantages. This article summarizes some of the more important things that have been learned about the use of open coil annealing during the past two years.

EQUIPMENT

The equipment needed for open coil annealing has been described by J. Arnold in the August, 1960 issue of *Iron and Steel Engineer*.[1]* Nevertheless, a brief description of the equipment is presented herein to facilitate understanding of how the annealing method

* Numbers in parentheses refer to Bibliography at end of article.

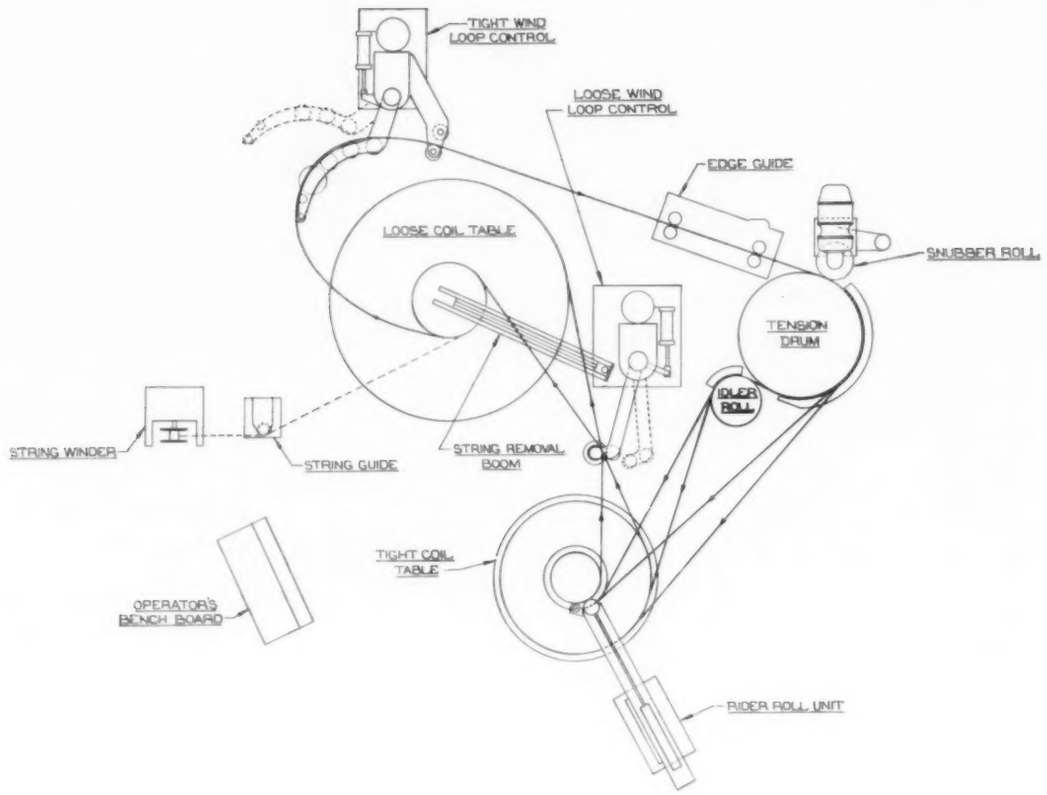
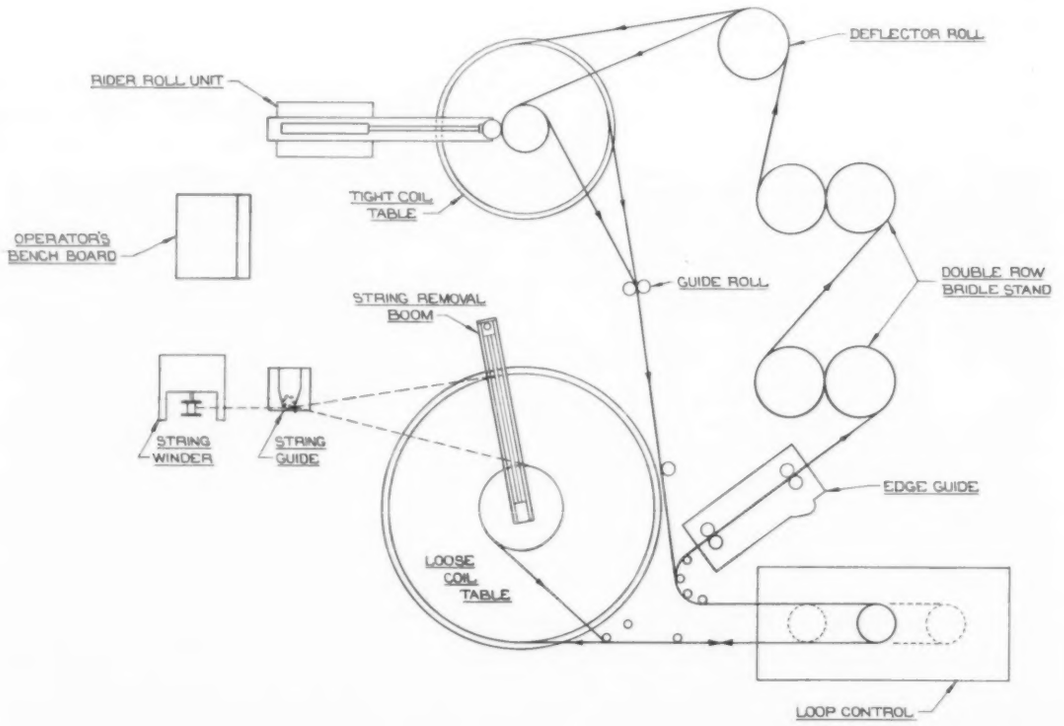


Figure 1 — Sheet gage coils are rewound using a large diameter tension drum.

can be used to produce new and improved flat-rolled products. The novel feature of open coil annealing is the provision of space or separations between the individual wraps of a coil so that hot annealing-atmosphere gas can be circulated through the separations. This means that the entire coil can be heated and cooled much more rapidly and more uniformly than in conventional box annealing. Also, it has now been found that desirable gas-metal reactions can be carried to completion when the coil is open during annealing.

A schematic diagram of the equipment designed to open sheet-gage coils before annealing and to rewind them into tight coils after annealing is shown in Figure 1. A schematic diagram of the equipment for winding coils of tin plate is shown in Figure 2. The basic differences between the two are: (1) for controlling tension, the sheet equipment includes a large-diameter tension drum, whereas the tin-plate equipment includes a 4-roll bridle stand, and (2) the loop control system used during winding from an open to a tight tin-plate

Figure 2 — Tin-plate coils are rewound using a 4-roll bridle stand at higher speeds than are applicable for sheet gage coils.



coil after annealing is of necessity designed to handle lighter gage strip at higher speed than the sheet loop control systems.

In the process as originally developed, the separations between wraps were obtained by means of a nylon string that was withdrawn from between the wraps before annealing of the open coil. The nylon string is still satisfactory for many kinds of annealing. However, when the annealing is done to change the composition of the steel by what has been referred to as "gas alloying," it is often advantageous to use a more positive method for maintaining uniform spacings between wraps. In these instances which will be discussed in detail later, the nylon string can be replaced, for example, by ¼-in. wide corrugated strip that remains in the open coil during annealing and that insures positive wrap separation without restricting flow of the hot gas through the coil.

A commercial sheet-coiling unit is shown in Figure 3, and a commercial tin-plate unit is shown in Figure 4. Both these views were made during the winding of an open coil with nylon string, and consequently neither the large tension drum in the sheet unit nor the bridle rolls in the tin-plate unit is being used. The tensioning units would be used during winding from an open to a tight coil after annealing. Commercial sheet units are designed to operate at speeds up to 1200 fpm during winding of an open coil before annealing and at speeds up to 800 fpm during winding of a tight coil after annealing. Commercial tin-plate units are designed to operate at 1500 fpm during winding of both open and tight coils.

In the open coil installations operating to date, annealing of the opened coils has been done in specially designed single-stack equipment with: (1) bases, inner-covers and furnaces capable of annealing opened coils with OD of 108 and 114 in.; (2) large base fans that circulate the hot annealing gas at 25,000 cfm; and (3) specially designed plenums and diffusers for circulating the gas up past the inner-cover and down through the opened coil. A schematic diagram showing this equipment, and the flow path of atmosphere gas is presented in Figure 5.

Design and engineering work are virtually completed on a rotary hearth furnace of the type shown in Figure 6 that will permit conventional annealing at much lower cost than in the special single-stack equipment mentioned previously. By conventional annealing is meant annealing merely to recrystallize and soften the steel without significantly changing its composition. The coil handling and winding equipment shown in the foreground of Figure 6 is designed to permit extensive automation, a complete installation of this type with a capacity of 20 tons per hr of sheet products can probably be operated by two men. Coils will move to and from the installation on conveyors and all the coils will be handled by a floor-mounted manipulator. The conveyors and manipulator are provided to eliminate the need for an overhead crane to deliver and position the coils.

The actual operation of the rotary hearth furnace can best be visualized by reference to Figure 7 showing the furnace with the roof removed. The opened coil enters the furnace through the entry purge chamber, moves counterclockwise on the rotating hearth from station 1 through 8 and leaves the furnace through the exit purge chamber. In this design for sheet-steel annealing, the hearth moves one station per hr: one annealed coil is delivered per hr. Stations 1, 2 and 3 are heating stations, and stations 6, 7 and 8 are cooling stations. Ecomony of operation is obtained by circulating the annealing gases between the heating and cooling stations, and consequently, very little external heat is needed to raise the temperature of the entering coils from room temperature to the annealing temperature. The warm gases from the coil being cooled in station 7, next to the last cooling station, will be circulated through the coil in station 1, the first heating station. Similarly, stations 6 and 2 will be paired. In the last heating station, station 3, and during the soak period in stations 4 and 5 (two-hr

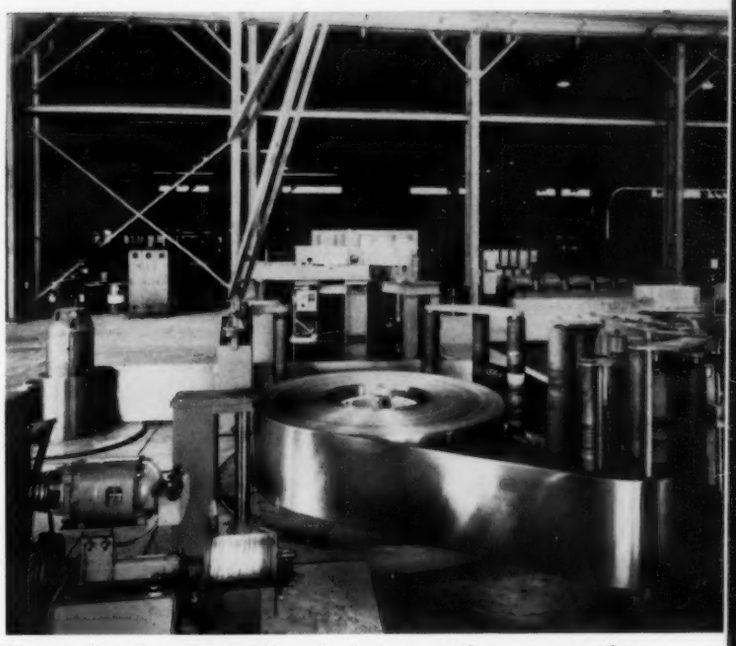
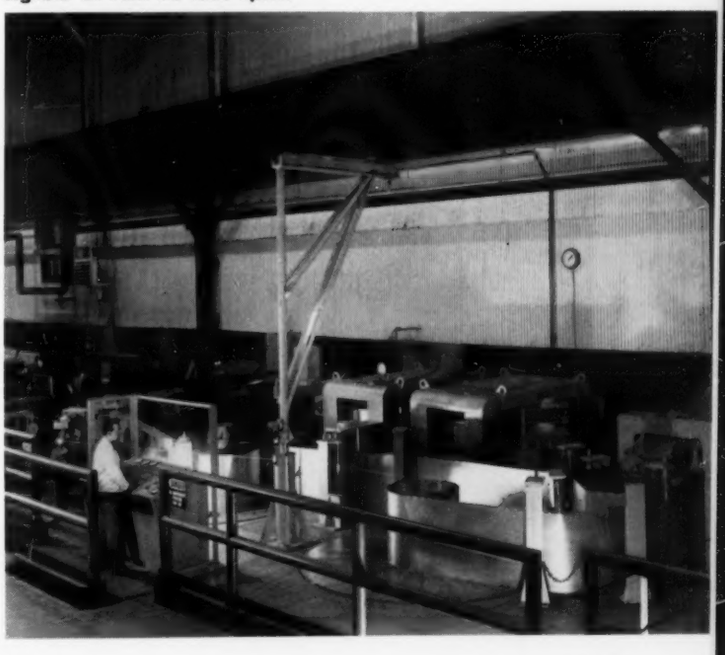


Figure 3 — A nylon string is being used to space the opening of the coil wraps.

Figure 4 — Tin-plate open coil-annealing systems are designed to run at 1500 fpm.



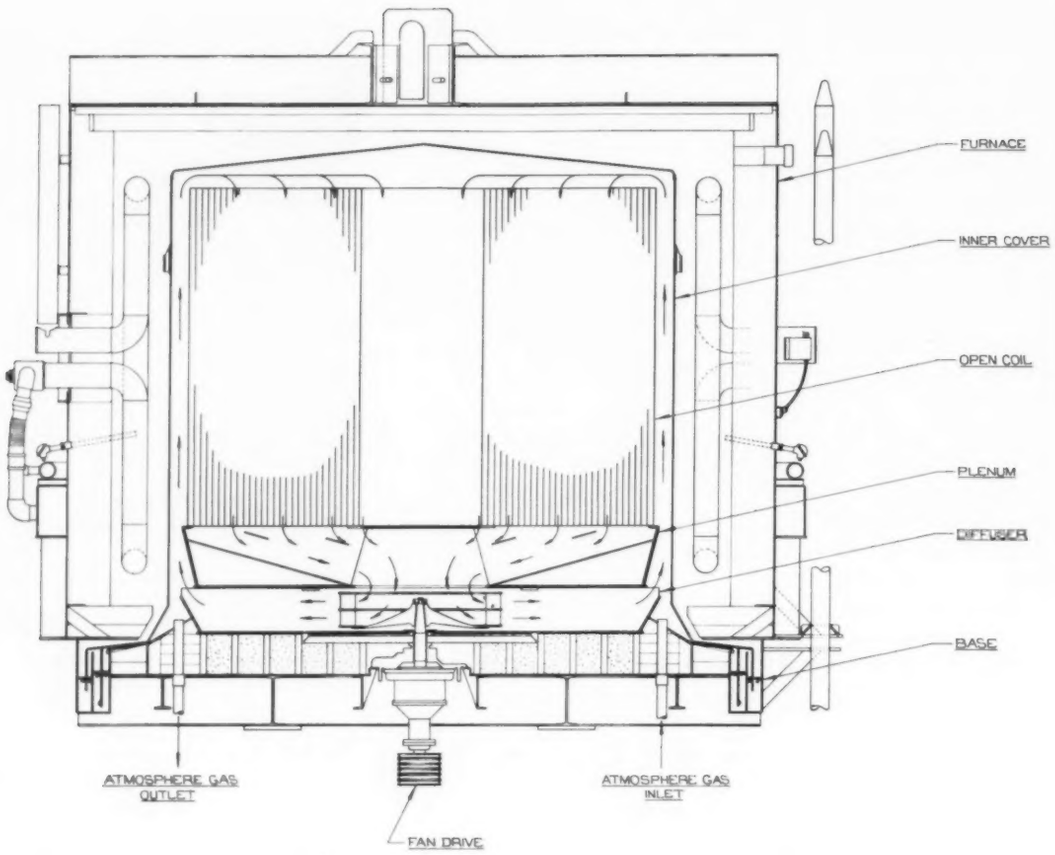


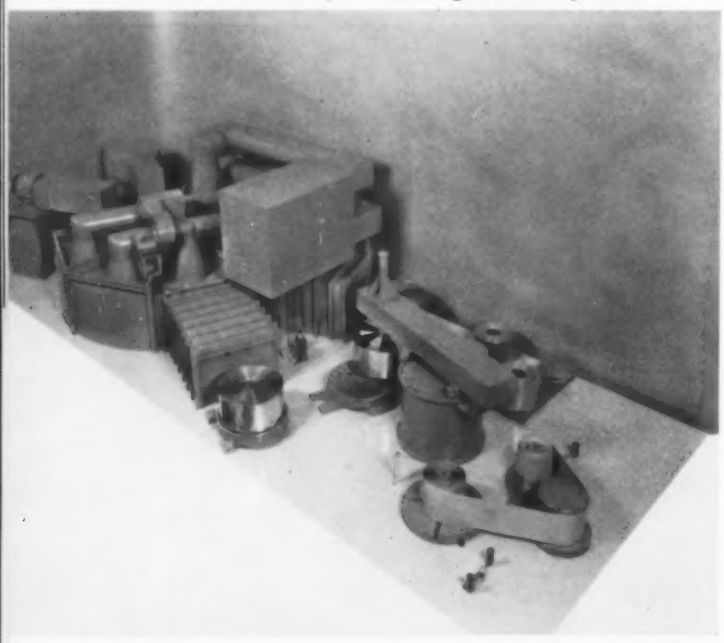
Figure 5 — Atmosphere gas is forced up outside of the coil and down through the opened laps of the coil.

total time), external sources of heat will be used to raise the temperature of the coil to the annealing temperature and to maintain the coil at this temperature during the soak. Final cooling in station 8 is accomplished by recirculating the gas used in this station through an external heat exchanger.

EXPERIMENTAL ANNEALING STUDIES

During the past four years about 800 coils of steel have been annealed on the pilot open coil-annealing installation. The pilot installation includes slow-speed coiling equipment for open and tight winding of coils up to 50-in. wide, one special single-stack furnace and two bases and a generator for the production of deoxidizing annealing gas. Facilities are also available for mixing bottled hydrogen and nitrogen gas in any proportion, and for adding controlled quantities of water vapor to the annealing-atmosphere gas. A gas chromatograph and dew point measuring equipment are available for determining the composition of the entry and exit atmosphere gas throughout the annealing cycle.

Figure 6 — Rotary hearth furnace operation promises lower cost than the open coil single-stack operation.



Both black plate and sheet-gage coils have been successfully coiled and annealed on this pilot equipment. Most of the coils which were of various weights in the range from about 4 to 13 tons, were annealed "one-high," but some were annealed "two-high." The maximum pile height of steel in the pilot equipment is limited to 66 in. by the height of the inner-cover.

All the annealing studies described in the following sections were made on this pilot equipment with coils supplied by various steel companies.

Temperature distribution—To measure temperature distribution during the entire annealing cycle, thermocouples were located at six locations in a number of open coils. The typical results presented in Table I were obtained during the annealing of a 6½-ton coil of 20-gage sheet steel that had been opened with nylon string. During the heating part of the cycle, the temperature near the inside (eye) of the coil at the middle and at bottom tended to be lower than that of the remainder of the coil by from 50 to 150 F. By the end of the heating period (3½-hr elapsed time), the temperature at the middle inside location was the same as elsewhere in the coil; and shortly after the start of soaking (4½-hr elapsed time), the temperature at the bottom

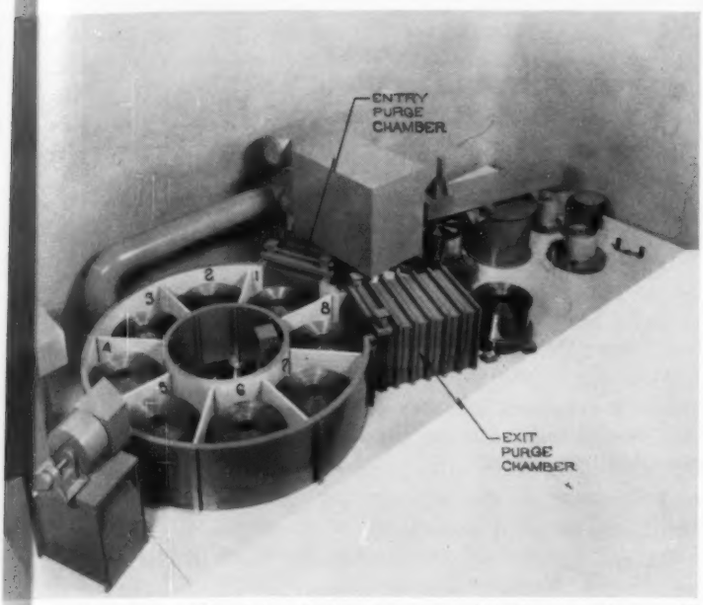


Figure 7 — Gas circulation between heating stations will reduce the heat input requirements.

inside location was only about 25 F lower than the temperature elsewhere in the coil. During the remainder of the soaking period (5 to 7-hr elapsed time), the maximum variation in temperature throughout the coil was 30 F, the lowest temperature being 1300 F at the bottom inside location after 5-hr elapsed time and the highest being 1330 F at the top outside location after 5½-hr elapsed time.

The rapid rate of cooling indicated by the data in Table I was obtained by the use of a forced cooler that blows air over the inner-cover in much the same fashion as with conventional single-stack annealing equipment. When the steel temperature reaches about 550 F, water is sprayed over the inner-cover to increase the cooling rate down to uncovering temperature. The coil used to obtain the data presented in Table I was uncovered after about 12-hr total elapsed time.

Conventional annealing of sheets—Samples from six 20-gage cold-reduced rimmed steel coils and from five 20-gage cold-reduced aluminum-killed steel coils were obtained from six steel companies. The samples were selected from random coils and exhibited the ranges of composition shown in Table II. A 9-ton coil was opened with the nylon string and samples, 12-in. long by coil width (about 36 in.), from each of the six rimmed steels and from each of the five aluminum-killed steels were inserted between the wraps of the 9-ton dummy coil. The same dummy coil was used with different samples to conduct anneals for times in the range from ½ to 4 hr at temperatures in the range from 1260 to 1340 F. Deoxidizing annealing gas produced with an air-to-gas ratio of six to one was used for all the anneals.

The average hardnesses of the annealed rimmed-steel samples are presented in Figure 8. The softest product was obtained by annealing at 1320 F, and annealing for 4 hr at this temperature gave very little advantage over annealing for one and for two hr. Annealing at 1300 F and at 1340 F gave slightly higher hardness than annealing at 1320 F, but again annealing for one and two hr at 1300 F and at 1340 F seem sufficient to develop satisfactory hardness. It appears that rimmed steel open coil annealed for one to two hours in the range 1300 to 1340 F will develop about the same hardness as rimmed steel that has been annealed for much longer times by conventional box-annealing methods.

The average hardness results obtained on the aluminum-killed steel samples, which are presented in Figure

TABLE I
Temperature Distribution During Open Coil Annealing*

Part of cycle	Elapsed time, hr	Temperature at indicated location in coil, F								
		Top			Middle			Bottom		
		Outside	Center	Inside	Outside	Center	Inside	Outside	Center	Inside
Heating	½	410	390	420	365	390	365	370	370	330
	1	760	720	750	705	725	685	695	690	640
	1½	1020	990	1020	990	990	950	960	930	890
	2	1255	1205	1245	1200	1210	1150	1175	1100	1050
	3	1305	1320	1335	1310	1290	1240	1290	1230	1135
	3½	1310	1310	1320	1310	1300	1290	1300	1280	1240
Soaking	4	1320	1320	1320	1320	1310	1310	1315	1310	1280
	4½	1320	1320	1320	1320	1310	1315	1320	1310	1295
	5	1320	1320	1320	1320	1310	1315	1320	1310	1300
	5½	1330	1320	1325	1320	1310	1320	1320	1310	1310
	6	1320	1320	1325	1320	1310	1320	1320	1310	1310
	6½	1320	1320	1325	1320	1310	1320	1320	1320	1310
	7	1310	1310	1315	1320	1315	1320	1320	1320	1310
Cooling	7½	1205	1205	1205	1210	1200	1205	1200	1190	1210
	8	995	1015	1000	960	1045	1010	1000	1115	1045
	8½	860	875	875	855	940	870	870	950	890
	9	740	750	750	755	800	770	770	780	770

* Top and bottom locations were about 1½ in. from the top and bottom edges of the coil, respectively; outside and inside locations were about 1½ in. from the outer and inner wraps of the coil, respectively.

TABLE II
Ranges of Composition of the Samples Used in Study of Open Coil-Annealing Temperatures and Times, Per Cent

Steel	C	Mn	P	S	Si	Cu	Al
Rimmed	0.04 to 0.10	0.31 to 0.45	0.004 to 0.017	0.024 to 0.028	0.01 to 0.02	0.04 to 0.24	...
Aluminum-killed	0.04 to 0.06	0.15 to 0.38	0.007 to 0.018	0.024 to 0.028	0.01 to 0.02	0.04 to 0.12	0.05 to 0.06

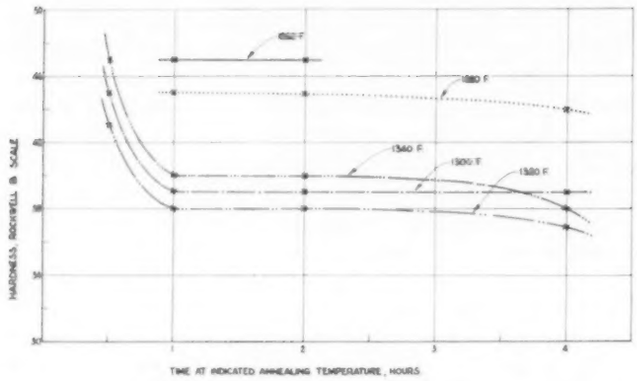


Figure 8 — Several samples of 20-gage rimmed steel were annealed by the open coil process to determine hardness data.

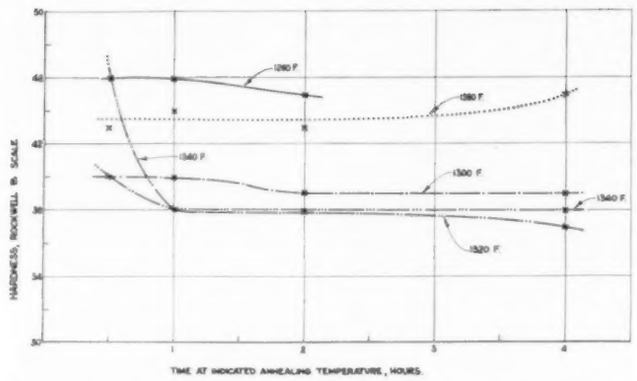


Figure 9 — Several samples of 20-gage aluminum-killed steel were annealed using the open coil process to determine hardness data.

9, also indicate that little or no decrease in hardness is obtained by extending the time at temperature from two to four hr. As was observed for the rimmed steels, annealing the aluminum-killed steels for one and two hr at 1260 and 1280 F resulted in significantly higher hardness than did annealing for these times at 1300 to 1340 F.

Several additional trials were made on both the rimmed and the aluminum-killed steels with time at temperature extended to eight hr. This long annealing time did not result in a significant hardness decrease.

Subsequent to completion of the work on these samples, annealing studies were conducted on coils of both rimmed and aluminum-killed steel. The results presented in Table III were obtained on 13-ton coils of 20-gage steel that were annealed for two hr at 1340 F in deoxidizing gas supplied to the charge at about 500 cfhr. The annealed coils were temper rolled in the normal fashion for drawing-quality sheets (about ½ per cent extension), and the mechanical properties and microstructure were determined at the edges and center of sheets obtained from the coils at locations corresponding to the outside, center and inside of the coil during annealing. The average mechanical properties and grain size were within the ranges normally observed for these steels after conventional box annealing. The total furnace time for these two coils was six hr, and the total base time was 14 hr. These times are much shorter than those required for conventional box annealing of drawing-quality sheets. Nevertheless, the uniformity of mechanical properties exhibited by these open coil-annealed coils was superior to that generally exhibited by conventionally box-annealed coils. It is of particular importance that the elongated grain structure, which is associated with the outstanding formability of box-annealed aluminum-killed steel in many difficult drawing applications, was developed by the short-time open coil-annealing cycle used.

Gas alloying—The fact that certain gases will react at elevated temperature with some of the elements in steel has long been known in the steel-producing and steel-consuming industries. For example, the steel producers are very much aware that the properties of high-carbon steels and constructional alloy steels can be deleteriously affected by surface decarburization during processing in the mill from ingot to finished product. On the other hand, steel consumers often carburize and nitride fabricated steel parts so as to impart increased hardness and wear resistance.

Except for the silicon steel sheets used in electrical equipment, which respresent a very special case from the metallurgical point of view, the known principles of gas-metal reactions during annealing have not been generally applied to the manufacture of flat-rolled products in the steel industry. The reason is quite simple and valid: suitable equipment in which the reactions could be economically and consistently accomplished was not available. Although the times involved in conventional box annealing are long, the active annealing gas does not have easy access to the surfaces of the steel in the tightly wound coil. As a consequence the reactions proceed very slowly and nonuniformly, and they are virtually impossibe to control. Although all the surface of the steel is exposed to the active annealing gas in continuous annealing, the steel is at the reaction temperature for too short a time to permit the reactions to proceed beyond the very preliminary stages.

In open coil annealing the entire surface of the steel coil can be exposed to the active annealing gas for as long as may be necessary for the steel-gas reactions to proceed to completion. As a consequence of these two features, complete exposure to the gas and unrestricted time at temperature, it has been found practical to change the composition of commercial size coils of flat-

TABLE III

Mechanical Properties and Grain Size of Open Coil-Annealed 20-Gage Sheet-Steel Coils

Property	Rimmed	Aluminum-killed
Hardness, Rockwell B		
Average	40	43
Range	37 to 44	42 to 45
Olsen cup depth, in.		
Average	0.41	0.42
Range	0.40 to 0.42	0.41 to 0.43
Yield strength, psi		
Average	29,200	26,900
Range	29,150 to 29,250	26,500 to 27,550
Tensile strength, psi		
Average	44,700	45,900
Range	44,400 to 45,100	44,900 to 46,700
Elongation,* per cent in 2 in.		
Average	39	39
Range	38 to 40	39 to 40
Grain size, ASTM No.		
Range	7 to 9	6 to 8
Shape	Equiaxed	Elongated

* The tension tests were made on longitudinal specimens.

rolled steel during open coil annealing and, to produce new, improved and lower cost steels. The following discussions summarize the results of some of the studies that have progressed furthest along this line.

Enameling steel—High-quality enameling sheets have long been made from low-carbon, low-manganese steel (0.03 per cent carbon, 0.08 per cent manganese) that is difficult to hot roll and to recrystallize. Furthermore, two separately applied enamel coats are necessary to insure that parts made from this steel are free of objectionable enamel defects. It has now been found that ordinary rimmed steel, which contains about 0.06 per cent carbon and 0.40 per cent manganese and which is easy to hot roll and recrystallize, can be made into a very satisfactory enameling steel by open coil annealing to remove almost all the carbon from the steel. The decarburization can be successfully accomplished by annealing in either hydrogen-nitrogen gas or deoxidizing gas provided that controlled quantities of water vapor are added to the gas during the soak period of the anneal. The results obtained with two coils of rimmed steel, one annealed in hydrogen-nitrogen gas and one in deoxidizing gas, are presented in Table IV. During the heating and cooling parts of the cycles described in this table, the eight per cent hydrogen gas was supplied to the base at about 300 cfhr, but during the soak, the gas flow rate was increased to about 900 cfhr to insure a sufficient supply of gas for reaction with the carbon in the steel. The +70 F dew point during soak with the eight per cent hydrogen gas and the +40 F dew point during soak with the cracked gas were obtained by introducing steam into the gas stream.

Gas analyses revealed that significant quantities of carbon monoxide (up to 2 per cent) were present in the outlet gases during about the first four hr of soak in the moist eight per cent hydrogen gas used with coil A and that there was about the same difference in the carbon monoxide content of the inlet and outlet gases during the first four hr of soak in the moist deoxidizing gas used with coil B. Also, for coil A annealed in the eight per cent hydrogen gas, the dew point of the outlet gas did not increase to the same level as that of the inlet gas until after no evidence of carbon monoxide was observed in the exit gas. This would indicate that the carbon at the steel surface reacts with the oxygen in the gas, which is present as water or as water and carbon dioxide, to form carbon monoxide. More importantly, however, accurate measurements of carbon monoxide in the outlet gas, supplemented by measurements of the dew point of the outlet gas, may provide a positive means for deciding when the soak period for a particular enameling-steel charge should be ended.

As shown in Table IV the carbon contents of both coils A and B were reduced to a very low level by the open coil-annealing treatments used. The hardness, tensile properties and grain size of coil A were as good as those generally observed for box-annealed drawing-quality rimmed steel and are typical of almost all the coils annealed to date under similar conditions. On the other hand, the hardness of coil B was unusually high and its grain size was unusually coarse, probably due to some feature in processing prior to annealing. Nevertheless, sheets from coil B were successfully fabricated into range tops and architectural panels that are normally fabricated from softer conventionally annealed steel.

TABLE IV
Properties of Open Coil Annealed Enameling Steel

	Coil A	Coil B
Starting material	Rimmed steel; 0.06 per cent C, 0.40 per cent Mn; six tons; 20 gage.	Rimmed steel; 0.03 per cent C, 0.31 per cent Mn; five tons; 18 gage.
Annealing cycle	1. Heated in four hr to 1300 F in dry eight per cent hydrogen, 92 per cent nitrogen gas. 2. Soaked for six hr at 1300 F in the eight per cent hydrogen gas with a dew point of +70 F. 3. Purged with dry eight per cent hydrogen gas for 1½ hr before cooling. 4. Cooled in six hr to 250 F in dry eight per cent hydrogen gas.	1. Heated in 3½ hr to 1350 F in dry eight per cent hydrogen, 92 per cent nitrogen gas. 2. Soaked for six hr at 1350 F in deoxidizing gas (seven to one air to gas ratio) with a dew point of +40 F. 3. Purged with dry eight per cent hydrogen gas for two hr before cooling. 4. Cooled in six hr to 250 F in dry eight per cent hydrogen gas.
Carbon content, per cent	0.002	0.002
Hardness, Rockwell B	38	47
Yield point, psi	28,000	...
Tensile strength, psi	42,000	...
Elongation, per cent in 2 in.	44	...
Grain size, ASTM No.	8 to 9	5 to 6

Since the 2-coat enameling characteristics of ordinary rimmed steel annealed as shown in Table IV are excellent, it can be substituted for the difficult-to-roll low-metalloid steel that has heretofore been the standard enameling-grade steel. However, of even greater importance is the fact that this open coil-annealed steel can be enameled satisfactorily with one white or light-colored coat. It is not necessary to apply the dark blue ground coat of enamel that has been used on low-metalloid steel as the base for subsequent application of a white or light-colored exterior coat on the exposed surface of appliances and architectural panels, for example. The excellent "direct-on" enamelability of the open coil-annealed steel has been well established by many tests made to date in the enameling industry, and several companies are offering the product for commercial delivery. As more of the open coil-annealing installations are placed in operation and the availability of the product increases, it will probably replace most of the low-metalloid steel now used in the enameling industry. Depending upon economics the open coil-annealed steel may also replace the box-annealed rimmed steel that is presently being used for noncritical enameling applications.

Because a relatively long soak (six hr) in moist atmosphere gas is required to produce the enameling steel, it would not be economic or practical from an operating viewpoint to use the rotary hearth furnace. However, work on the open coil pilot equipment has demonstrated that the special single-stack furnaces can be used and that coils can be annealed 2-high with satisfactory results. The top coil can be placed directly on the bottom coil, no special supporting framework being needed for the top coil. Serious edge damage and coil buckling has not occurred in the opened coils provided that the bottom coil is 24 gage or heavier and that the temperature

of the steel does not exceed about 1400 F. Higher temperatures may be permissible, but annealing trials must be made to establish the upper temperature limit.

Nonaging steel—It is characteristic of rimmed steel to age during storage after complete processing in the steel mill. The aging is manifested by an increase in hardness, a decrease in ductility and formability and a return of the yield point. When the utmost in formability and stability of properties is required in a particular application, therefore, it is generally the practice to use a nonaging aluminum-killed steel. Aluminum-killed sheet steel is more expensive than rimmed steel and it has a poorer surface. Therefore, the steel industry has long been searching for a product that will combine the excellent surface quality of rimmed steel with the nonaging and excellent forming quality of aluminum-killed steel. Vanadium-treated steel and boron-treated steel, for example, were developed mainly to meet this objective, but neither has been generally accepted as the product combining the desirable properties of present rimmed and aluminum-killed steel. Open coil annealing offers another way in which the desired new product may be produced.

About 20 years ago Low and Gensamer[2] found that samples of rimmed-steel sheet could be made nonaging by laboratory-scale annealing in moist hydrogen gas. Until the advent of open coil annealing, however, commercial equipment was not available for the application of Low and Gensamer's findings to the processing of commercial-size coils of sheet steel. Experimental work is in progress to determine the most economical annealing conditions for producing coils of nonaging rimmed steels. A discussion of the annealing cycles found successful to date, along with the properties of the product, seems worthy of presentation at this time.

An interesting study of annealing variables was made on three 5-ton coils of 19-gage cold-reduced rimmed steel with the following composition: 0.04 per cent carbon, 0.25 per cent manganese, 0.009 per cent phosphorus and 0.022 per cent sulphur. Each of the three coils was wound into an open coil with corrugated banding that was left in the coil during annealing and was annealed in a 1-high charge. All three coils were heated and cooled in dry eight per cent hydrogen, 92 per cent nitrogen gas, and the important features of the soaking part of the cycle are presented in Table V. Samples were obtained from the inside and outside of each annealed coil, and samples cut from the head and tail of each cold-reduced coil were inserted between the center wraps of each coil during annealing. These samples were used to determine the aging index, hardness, tensile properties, microstructure, and composition of the steel after annealing.

The aging index was determined as follows:

1. Strain three sets of duplicate tension-test specimens from each location to six per cent strain, and calculate the stress at six per cent strain.
2. Remove the specimens from the testing machine and age one duplicate set for 20 hr at 120 F, one set for four hr at 212 F and one set for ½ hr at 400 F.
3. Continue the tension test and calculate the yield strength of the aged specimens.
4. The percentage difference between the stress at six per cent prestrain and the yield strength after aging is the aging index.

TABLE V
Experimental Annealing Treatments to Produce Nonaging Rimmed Steel

Coil	Temperature, F	Time, hr	Atmosphere gas, per cent hydrogen*	Dew point, F	Inlet flow rate, cfhr
C	1350	23	100	80 to 100	1500
D	1350	19	70	80 to 100	3000
E	1350	25	50	80 to 100	3000

* Balance nitrogen.

TABLE VI
Results of Strain Aging Tests

Steel	Aging index, per cent: after aging for		
	20 hr at 120 F	4 hr at 212 F	½ hr at 400 F
Rimmed steel control	19	25	26
Aluminum-killed control	3	6	9
Coil C	0	0	0
Coil D	0	1	0
Coil E	12	14	17

The aging indices of the three coils that were annealed as shown in Table V are summarized in Table VI along with similar results obtained on control samples of box-annealed rimmed and aluminum-killed 20-gage sheet steel. As might be expected, the aging index of the rimmed-steel control was high for all three aging treatments studied. Although aluminum-killed steel is commonly referred to as a nonaging steel, the aging treatments used in these tests were sufficiently severe to cause a small but significant amount of aging in the aluminum-killed control steel.

Experimental coils C and D exhibited no aging in these tests, and experimental coil E exhibited aging intermediate to that of the rimmed and aluminum-killed control steels. Work is currently underway to determine the minimum time and gas flow rate required to produce a nonaging steel with a 100 per cent hydrogen atmosphere and with a 70 per cent hydrogen atmosphere. It is also planned to investigate the effects of higher dew points (up to 140 F) with improved saturating equipment that has been installed at the pilot plant for moistening the annealing gases. The excellent results obtained on coil D, which was annealed in a gas containing 70 per cent hydrogen and 30 per cent nitrogen, are of particular importance because they indicate that up to 30 per cent nitrogen can be tolerated as an impurity in the annealing gas without seriously impeding removal of nitrogen from the steel. On the basis of the results for coil E, it appears that the use of a gas with 50 per cent nitrogen may require extending the soak time beyond practical limits. The 70 per cent hydrogen gas used in the annealing of coil D was made by mixing high-purity bottled hydrogen and nitrogen. Nevertheless, it appears that the nonaging steel could be produced by annealing in cracked ammonia or in hydrogen gas generated from natural gas provided that they do not contain significant quantities of undesirable contaminants such as ammonia, methane and carbon monoxide. Obviously

the economics of this annealing treatment are much more favorable if cracked ammonia or generator hydrogen can be used rather than high-purity bottled hydrogen. Further work is underway to determine the kinds and quantities of contaminants that can be tolerated in the atmosphere gas.

As shown in Table VII there was little variation in the tensile properties and hardness of the three coils annealed in this study even though steel E exhibited strain aging and steels C and D did not. Furthermore, the yield strengths of the two nonaging steels C and D were considerably higher than expected. The high yield strengths may be partly explained by the fine grain size of the annealed steels, ASTM 7½ to 8, but other presently unknown factors must also have had an effect. In this regard it should be mentioned that the carbon content of all three steels was about 0.001 per cent and the nitrogen content was below the limit of reliable analysis by conventional methods.

In summary sufficient work has been done to establish that open coil annealing can be used to produce commercial quantities of nonaging rimmed steel by removing carbon and nitrogen from the steel as first accomplished by Low and Gensamer[2]. The most economic annealing conditions to achieve this end are now being established, and of equal importance, the formability of the product is being evaluated in actual deep-drawing applications.

As for the open coil annealing of the enameling steel, open coil annealing to produce nonaging rimmed steel will require relatively long soak times in moist atmosphere gas. The rotary hearth furnace is not suitable for this kind of annealing, and the special single-stack furnaces will probably have to be used.

Tin plate—Box annealing is well suited for production of the soft tin-plate tempers, but not the hard tempers. Continuous annealing is well suited for production of the hard tin-plate tempers, but not the soft tempers. Sufficient work has been done to establish that all the tempers of tin plate from T-1 through T-6, including T-U, can be made by the open coil annealing of standard tin-plate steels. For T-6, beer-can end stock, this means using a rephosphorized steel. For T-U product, this means using a nitrogenized steel (0.006 to 0.008 per cent nitrogen) to obtain an average hardness of 65 Rockwell 30-T; steel without added nitrogen can be used to obtain average hardnesses at the low end of the T-U range (62 to 68 Rockwell 30-T). When the steel composition is varied in this normal fashion to produce the various tempers, the open coil-annealing time can be standardized at ½ hr and the annealing temperature can be varied to obtain the desired hardness level in the annealed steel. For example, T-4 product would be annealed at about 1150 F, T-U product at about 1100 F, and T-6 product at about 1200 F. The rotary hearth furnace is ideally suited for this kind of annealing. Annealing times would be much shorter than in box annealing, stickers would not be a problem, and the equipment would be much more flexible than continuous-annealing equipment.

Present research on tin plate at the open coil pilot plant is being conducted with the objective of developing an open coil-annealing cycle that will eliminate the need for using rephosphorized steel to make beer-can end stock. If open coil annealing can be used to remove the nitrogen from plain-carbon steel and thereby render it nonaging, it seemed to follow logically that nitrogen could be added to plain-carbon steel and thereby render it harder and stronger. The results to date have been very encouraging.

TABLE VII
Mechanical Properties of Coils C, D and E in the As-Annealed Condition

Coil	Yield strength, psi	Tensile strength, psi	Elongation per cent in 2 in.	Hardness, Rockwell B
C	26,800	40,800	44	31
D	25,800	40,200	46	33
E	25,200	39,800	43	30

Cold-reduced black plate made from a normal tin-plate grade of steel (0.08 per cent carbon, 0.33 per cent manganese, 0.009 per cent sulphur, 0.015 per cent phosphorus and 0.003 per cent nitrogen) has been open coil annealed as shown in Table VIII, using ammonia during heating to 1000 F as the source of nitrogen. Heating from 1000 to 1150 F and soaking for ½ hr. at 1150 F in dry eight per cent hydrogen gas served to diffuse the nitrogen uniformly throughout the thickness of the steel; metallographic examination revealed no nitrided case on the steel. Analyses of samples located at the outside, center and inside of the open coil during annealing indicated that the nitrogen content of the coil was in the range from 0.025 to 0.036 per cent. Furthermore, the hardness of the annealed steel at these locations varied from 68.5 to 72.0 Rockwell 30-T. Inasmuch as the hardness of the steel will increase by from two to five Rockwell 30-T as a consequence of temper rolling and tinning, it seems certain that beer-can ends made from the tin plate will exhibit strength at least as high as that of conventional beer-can end stock made from rephosphorized steel. If the strength of the nitrogenized tin plate is significantly greater than that of conventional beer-can end stock, it should be possible to reduce the basis weight (thickness) of beer-can end stock without sacrifice in the buckling strength and rigidity of the can ends.

It seems entirely possible that open coil annealing will permit the production of all the tin-plate tempers from one grade of steel. For the T-U and T-6 tempers, the nitrogenizing technique described above could be used to obtain 0.015 to 0.020 per cent nitrogen for T-U

TABLE VIII
Production of Beer-Can-End Tin Plate from Plain-Carbon Steel (Not Rephospherized)

Annealing cycle.....	1. Purge with dry eight per cent hydrogen, 92 per cent nitrogen gas at 900 cfhr. 2. Heat to 1000 F in about 1½ hr in ammonia gas supplied to the base at 200 cfhr. 3. Heat from 1000 to 1150 F in about ½ hr and soak for ½ hr at 1150 F in the dry eight per cent hydrogen gas supplied to the base at 500 cfhr. 4. Cool in about three hr to 250 F in the dry eight per cent hydrogen gas supplied to the base at 500 cfhr.
Nitrogen content after annealing.....	0.025 to 0.036 per cent
Hardness after annealing.....	68.5 to 72.0 Rockwell 30-T

and about 0.030 per cent nitrogen for T-6. For the softer tempers, T-1 through T-4, the annealing temperature could be varied so as to provide product in the desired hardness range. Since the soaking time is short (½ hr), the rotary hearth furnace should be suitable for all these annealing treatments, including the nitrogenizing anneals.

Other applications of open coil annealing—The work on enameling steel discussed previously has clearly indicated that the carbon content of plain-carbon steel can be consistently reduced to a very low level (about 0.005 per cent or less) by open coil annealing. The carbon content of steel with up to about 2½ per cent silicon can also be consistently reduced to this very low level by open coil annealing. Since the magnetic properties and magnetic-aging tendency of steel improve as the carbon content is decreased, it follows that open coil annealing should be well suited for the processing of plain-carbon and low-silicon steel sheets intended for application in electrical machinery. Indeed, several steel companies are actively working on the use of the annealing method for the production of these grades of sheet steel, and the preliminary results are very encouraging.

Of the many other potential applications of open coil gas alloying, three are of particular importance because, if successful, they would represent major advancements in the processing of flat-rolled steel products. First, there is the possibility of using the principles of gas carburizing to produce high-carbon sheet by carburizing cold-reduced low-carbon steel during open coil annealing. Gas carburizing techniques are well developed and case depths equal to half the thickness of sheet steel are common. Significant savings in hot and cold-rolling costs should be realized by eliminating the necessity of rolling high-carbon steel. Second, there is the possibility of making substitutes for chromium stainless steel (for example, AISI Type 430) by diffusing chromium into plain-carbon steel during open coil annealing in an atmosphere containing gaseous chromium. The economy in being able to concentrate the chromium at the strip surface to resist corrosion is obvious. Third, there is the possibility of changing the character and composition of the steel surface by causing it to react with elements and compounds in the annealing atmosphere. For example, surface treatments like phosphating to improve the rust resistance and painting properties of steel might be accomplished in this fashion.

It is planned to study these three potential applications of open coil annealing, along with numerous other possibilities, as time permits on the open coil pilot equipment.

SUMMARY

The results of experimental work to date on the pilot open coil-annealing equipment have indicated that the annealing method can be used to produce drawing-quality sheet steels with very uniform mechanical properties. In the experimental work properties equivalent to those of conventionally box-annealed rimmed and aluminum-killed steels were developed with a soaking time of two hr. Also, it has been found that all the tin-plate tempers can be produced by open coil annealing of the normal grades of tin-plate steel.

For the most economical annealing of drawing-quality sheets and of tin plate, a rotary hearth furnace with the necessary coiling equipment has been designed.

Because all the surface of the cold-reduced steel is exposed to the annealing atmosphere for as long as desired, gas-metal reactions can be promoted and controlled during open coil annealing. It has been well established that an enameling steel superior to the current standard enameling steels can be produced by the decarburizing of normal rimmed steel during open coil annealing. When the carbon content of rimmed steel is reduced to 0.005 per cent or less by open coil annealing for about six hr in moist annealing gas (eight per cent hydrogen, 92 per cent nitrogen gas and deoxidizing gas), the steel is suitable for conventional 2-coat enameling as well as for 1-coat or direct-on enameling. It has also been determined that nonaging rimmed steel can be produced by removing virtually all the carbon and nitrogen from the steel during open coil annealing in moist hydrogen and in moist 70 per cent hydrogen, 30 per cent nitrogen gas. Further work is underway to determine the most economical annealing cycle and atmosphere gas that can be used to produce the nonaging rimmed steel.

Results have also indicated that it should be possible to produce beer-can end stock (T-6) from plain-carbon steel instead of the more expensive, difficult-to-roll rephosphorized steel that is currently used. The nitrogen content of cold-reduced coils of low-phosphorus steel has been increased from about 0.003 to 0.030 per cent by short open coil-annealing cycles using ammonia as the source of the nitrogen. The nitrogen is uniformly distributed through the thickness of the steel, and the hardness of the annealed steel is somewhat higher than that of the conventional rephosphorized product.

Of the many possible applications of open coil annealing, the following three are of outstanding potential benefit to the steel industry and are being studied as time permits on the pilot equipment.

1. Production of high-carbon sheet by the carburization of cold-reduced low-carbon sheet.
2. Production of substitutes for the chromium grades of stainless steel by the chromizing of plain-carbon steel sheet.
3. Surface treatment of sheet during annealing.

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Discussion

PRESENTED BY

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J. W. Hill: The author's paper implies that a great deal of chemistry will come into play with the open coil-

annealing system, and as the main function of this anneal is contact of gases to every sq in. of coil surface it brings up a question on gas concentration. Various gases bring about chemical changes and these changes are not accelerated by quantity but only by increasing the concentration. In view of this, has any thought been made regarding the pressurizing of the open coil anneal?

Is there a possibility of this equipment producing silicon steel from plain carbon by the injection of silicon tetrachloride or similar gases?

How does this equipment withstand alternate oxidation-reduction processes for the surface treatment of steel?

J. A. Bauscher: In connection with the matter of pressurizing, no work has been done along this line, nor has increasing pressure been seriously considered beyond the normal one in. of water because liquid seals are generally used on this type of furnace equipment. Therefore, it would not be possible to do much pressurizing inside the inner-cover unless something radically different than the conventional oil or sand seal is developed. However, for certain reactions high pressure might be advantageous.

With regard to the diffusion of silicon into carbon steel to produce the equivalent of present silicon-bearing electrical sheets, it is being done now on a small scale using chlorine gas as a carrier and silicon carbide as the source of the silicon. There would undoubtedly be a great many engineering problems to solve in connection with safety and construction materials for large-scale equipment, since chlorine is not an easy gas to handle.

So far as alternate oxidation and reduction is concerned, the equipment at the pilot plant, in which the materials of construction are the same as in commercial installations, has been operated for more than 800 charges without any serious maintenance problems. As might be expected on pilot equipment being used in experimental operations, the conditions have varied frequently from oxidizing to reducing during one charge and from one charge to another.

J. D. Keller: In the open coil-annealing system, does the decarbonization and denitrification of the strip penetrate all the way through the thickness or is it only on the surface?

If the process penetrates all the way through, then there is something a little puzzling. In that case, why should contact of the adjacent layers of the open coil make a difference in physical properties?

Some who have done some experimenting with open coil annealing say that the decarbonization does occur at places where the layers of the coil are well separated, but in those points where there is contact, even very light contact (and you cannot avoid those at all times), in those places there is little decarbonization and you get local hard spots.

If the decarbonization goes all the way through, it is hard to understand why that should be, because you would expect if there is contact on one side of the strip that there would be a larger gap on the other side, and certainly the carbon ought to diffuse and be removed by the gas on the one side in spite of its contact on the other side. So the hard spots would not be expected.

How was the final content of carbon and nitrogen after annealing determined? It is understood that the determination or analysis of nitrogen content is difficult and chemical analysis is extremely difficult to make with any degree of accuracy, so I would like the author's statement as to which method was used to determine the carbon and nitrogen content.

If the strip has been carried down to 0.001 per cent carbon, is it usable? It would apparently be like ingot iron and would have a very low strength, be very soft and weak and would have to be cold reduced, at least ten per cent in the temper mill would be necessary to get it up to a reasonable strength for use.

Why first decarburize and then recarburize? Is one for a certain desired quality, and the other for an entirely different one?

How is the variation of the OD of the coil taken care of with regard to sealing it on the outer edge of the coil as the bottom? Formerly much was made of the supposed difficulty of doing any sealing because of the variation of the OD of the coil. What sealing means were used?

J. A. Bauscher: The work to date has dealt with annealing temperatures and times that will produce uniformly decarburized steel or decarburized and denitrogenized steel throughout the cross section of strip up to about 0.075-in. thick (14 gage). Decarburization can be evaluated relatively easily by microstructural examinations for the presence or absence of carbides and they can be supplemented by chemical analyses using methods that are fairly reliable when the total carbon content is not less than 0.001 per cent.

The problem of analyzing for nitrogen is more difficult. The studies to remove nitrogen from the steel were for the purpose of producing nonaging rimmed steel. Theoretically, there must be less than 0.0005 per cent nitrogen in solution in the steel, and there is no reliable method for analyzing nitrogen content at this low level. Therefore, the actual aging tendency of the steel was determined by means of the tests described in the paper. In a few cases internal friction techniques have been used to determine the carbon and nitrogen in solution in samples from coils that were made nonaging by open coil-annealing treatments. The results indicated less than 0.001 per cent carbon in solution and less than 0.0003 per cent nitrogen in solution.

Partial decarburization of the surface layer of the steel could probably be accomplished by decreasing the temperature and/or the time of the soak, but this might result in uncontrolled variations in the extent and consistency of partial decarburization throughout the coil.

The matter of laps in contact during open coil annealing probably depends on the type of product being treated, that is, a greater extent of contacting laps can be tolerated in one case than in another. Of the products discussed in the paper the nonaging steel represents the one in which the least possible degree of contactingl aps can be tolerated. When gas-metal reactions of any sort are part of the open coil treatment, however, it is important to avoid having many successive wraps in tight contact (for example, groups of more than three or four successive wraps) because of poor tension control during open coiling, excessively poor shape of the cold-rolled steel, or movement of the coil during heating. To avoid this possibility, positive

separating means are used, like the corrugated banding mentioned in the paper, which insures that a space is maintained between the successive laps in the open coil.

With regard to undersized coils, our practice at the pilot plant is to use pieces of steel strip to "mask off" the plenum and diffuser outside of the outer diameter of the coil, and consequently movement of the gas must be down through the coil rather than around it. This has worked satisfactorily and the units that are in commercial operation are doing the same thing with satisfactory results. In commercial operations of course it is better to maintain the OD of the coils as close as possible to the base diameter so as to obtain the highest production rate.

In Mr. Arnold's paper[1] he mentioned carbon restoration in connection with the higher carbon steels in which surface decarburization cannot be avoided during processing from ingot to final form. In these cases it is highly desirable to be able to raise the carbon content of the surface back up to the carbon content of the rest of the steel. However this article is concerned with treating low-carbon steel so as to obtain economies in rolling and fabricating (processing up to annealing), and then to carburize in the annealing stage to make a high-carbon steel. The main advantage would be savings in melting and rolling costs.

R. S. Burns: The author has pointed out the great advantage of the open coil process over conventional box annealing in allowing the annealing atmosphere to be circulated between the laps of the coil and hence in effect produce a continuous anneal of essentially infinite length. Soaking times may now be considered in hr rather than in min as is the case with conventional continuous annealing. The successful application of this process could revolutionize certain facets of the sheet steel producing industry and it is recognized that some advantages may be accrued from this method of annealing.

The author refers to the effect of open coil-annealing time and temperature on the hardness of rimmed and killed steel. Our experience has been that there is no essential difference between 38 and 42 Rockwell even when large numbers of tests are considered and hence it could be considered from these data that annealing temperatures between 1300 and 1340 F for one to four-hr soak are all equivalent. In rimmed steel that there is as much as 12 points Rockwell variation in hardness between top and bottom center of the ingot due to chemical segregation alone, even when laboratory annealing is performed at very uniform temperatures. This variation is not evident in the author's data and it is concluded that sampling was not adequate to indicate differences caused by segregation.

One further comment is that neither Rockwell values nor tension test values insure drawing quality under all circumstances and, therefore, die performance data is needed to evaluate the product of open coil annealing.

That development of nonaging properties by denitriding was demonstrated some 20 years ago by Gensamer and Low.[2] The possibilities of being able to produce nonaging rimmed steel by the open coil method are intriguing but there are two questions: one is the economics involved and the other is whether the nonaging rimmed steel with rounded grains can compete in drawability with aluminum-killed steel which has so-called "pancake grains."

Apparently something happened to coil E because it did not turn out to be nonaging, probably because the nitrogen was not removed. Nitrogen values for these aging experiments could be very informative. Perhaps 1350 F is too high a temperature to remove nitrogen and removal may be more efficient at 1100 to 1150 F.

J. A. Bauscher: We certainly agree that the hardness differences caused by variations in annealing temperature from 1300 to 1340 F for times in the range from one to four hr are inconsequential, and in view of other variables always present in steel they are insignificant. In the case of the samples investigated, however, the small effect of temperature was fairly consistent and seemed worthy of reporting. In view of the procedure used in obtaining the samples for the study, it was not expected that the segregation effects would be observed in the results obtained.

The shortcomings of both the hardness test and the tension test in predicting the drawing performance of sheet steels are recognized. The open coil-annealed cold-rolled sheets produced to date have performed at least as well as the equivalent sheets produced by conventional box-annealing procedures. Experience to date is insufficient to say whether open coil-annealed nonaging rimmed steel with equiaxed grains will perform as well as box-annealed aluminum-killed steel with elongated grains. The "R" values, on which Mr. Burns and his colleagues have done some excellent work, provide grounds for optimism. The "R" value of the nonaging rimmed steel (about 1.4) is more nearly like that of aluminum-killed steel than like that of normal rimmed steel. We are still working on the development of the most economical practice for producing the nonaging rimmed steel, and we expect the economics to be sufficiently favorable to encourage the steel companies to completely explore the matter of formability in commercial drawing applications now supplied with aluminum-killed steel. ▲

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Processing Equipment for Stainless Steel Bright Annealing

. . . . bright annealing produces a stainless strip surface which is suitable for many applications without the necessity of buffing or polishing . . . .

by S. FRIEDLANDER,
Engineer,
Production Machinery Corp.,
Mentor, Ohio

TODAY'S most common method of annealing stainless steel, between cold rollings, is to heat the strip to temperature in an open anneal, usually a catenary-type furnace, and then remove the resultant oxide by either mechanical means such as shot blasting, chemical means such as acid pickling, descaling in a molten salt bath, or a combination of these. In general the shot blast or molten salt bath descaling systems require final treatment by processing through an acid pickle in order to remove bits of spent shot or particles of oxide not previously removed. In the open annealing system, oxide built up on the surface consists of stabilizing elements, such as chromium and nickel (also silicon) in a slightly different percentage composition than in the parent material. Removal of this oxide skin leaves a surface on the parent material of a different chemical composition than was originally found, which changes the chemical activity of the material so that it is less resistant to corrosion. Only by removal of this surface can the material be changed to regain its original chemical corrosion resistance, and it is usually accomplished by mechanical means such as grinding or polishing.

Several industries, primarily the automotive industry, have upgraded their specifications for straight chrome stainless steel by incorporating a severe corrosion resistance test. It usually cannot be passed by a standard type 430 stainless processed by means of an open anneal and acid pickling arrangement. In addition there is a constant desire from all manufacturers to obtain a stainless steel having a very bright finish which does not require additional buffing or surface treatment after completion of the finished part.

These two requirements when applied to stainless steel can now be satisfactorily fulfilled by means of today's modern bright annealing process.

PROCESS DEVELOPMENT

Requirements for bright finish and improved corrosion resistance have been made practical at economical production rates by several new developments in the annealing field. The first was the development of a high-heat head furnace, which operates on the principle that the heat source be 400 to 600 F higher than the desired annealing temperature. For example, if a final strip annealing temperature of 1550 F is required, the furnace temperature may vary anywhere from 1900 to 2100 F. Strip, in passing through such a heating zone, will receive a material hardness and grain size in accordance with the proper control of the relationship between strip speed and furnace temperature. Second was the development of a high-speed cooling system which reduced the strip temperature at an extremely rapid rate. Third was the development of the vertical furnace which eliminated the use of the supporting rolls required in a horizontal furnace where the catenary could be long enough to require intermediate support. Use of intermediate support rolls almost invariably creates problems by causing small surface markings on the strip due to differential speeds between roll and strip. The vertical furnace, which completes its heating and cooling in one leg so that no roll will be in contact with the strip while it is at elevated temperature, provides an adequate solution to the requirements for practical production rates of bright annealed stainless.

FURNACE DESIGN

Vertical furnaces presently in operation are of several types. One type is an electric resistance unit

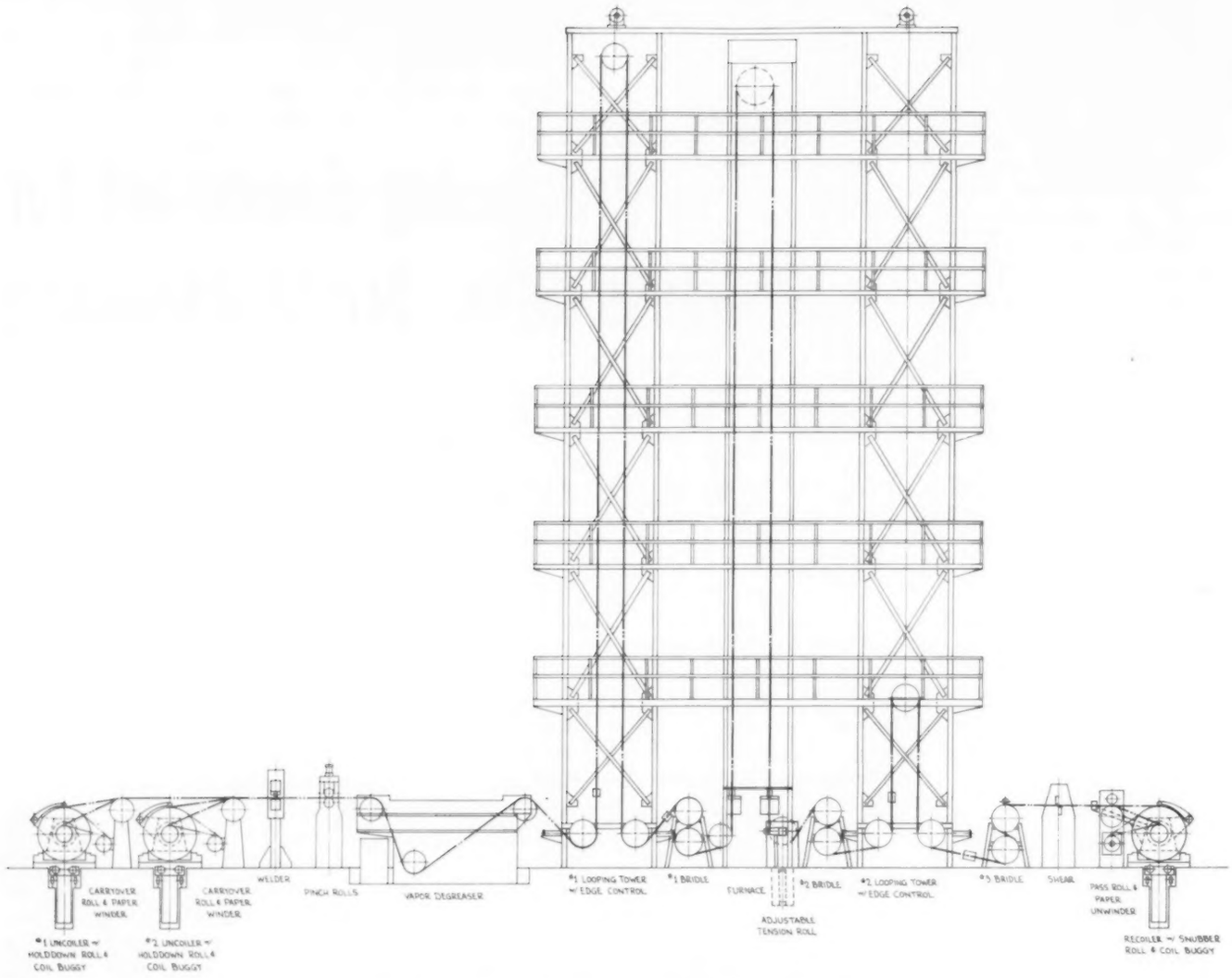


Figure 1 — The straight-through process line requires both entry and exit looping towers.

wherein the strip is heated primarily by radiation from elements to which the strip is directly exposed. This requires the use of very high purity brick and careful atmosphere control. Each of the units presently in use heats on the down leg only; that is the strip passes upward into the vertical furnace over a roll and downward into the heating zone, through the cooling zone and out into the terminal equipment.

The gas-fired muffle furnace is another type, wherein the strip is again heated by radiation, by a radiant muffle heated from the outside by means of gas burners, either of the radiant or the direct firing type. Of the gas-fired muffle-type units, one design heats and cools on the up leg and the strip then passes over the top roll in a relatively cool condition, then passes downward still in the furnace atmosphere and then outward to the terminal equipment. Another gas-fired type heats and cools on the down leg in a manner similar to the electric resistance heating unit.

To properly cool the material and retain the vertical furnace arrangement within practical limits required the development of high-speed cooling systems. This involves recirculation of the furnace atmosphere through water-to-gas heat exchangers, and the application of the cooled atmosphere directly against the strip through a blower and nozzle system.

Bright annealing furnaces presently have a production rate ranging from 2000 to 15,000 lb per hr in material gages from 0.003 to 0.109 in.

Atmosphere used in the bright annealing system is either dissociated ammonia or straight hydrogen. Either type is satisfactory, although the tendency exists to install a dissociated ammonia system due to its lower initial cost. The initial cost of a dissociated ammonia producer, including vaporizer and all auxiliaries, is approximately one third that of a hydrogen generation system. However, operating cost of the ammonia producer is greater than that of the hydrogen unit by approximately two to one, with the exact relationship dependent upon the cost of raw ammonia. In either case atmosphere is supplied to the furnace under pressure and is generally scavenged by means of air removal systems at points of strip entrance and exit.

MECHANICAL EQUIPMENT REQUIREMENTS

This article is primarily intended to encompass equipment arrangements suitable for production rates as determined by the previously described vertical furnaces. There are several possible configurations. Figure 1 illustrates a straight-through line with the uncoiling equipment on one side of the furnace and the re-

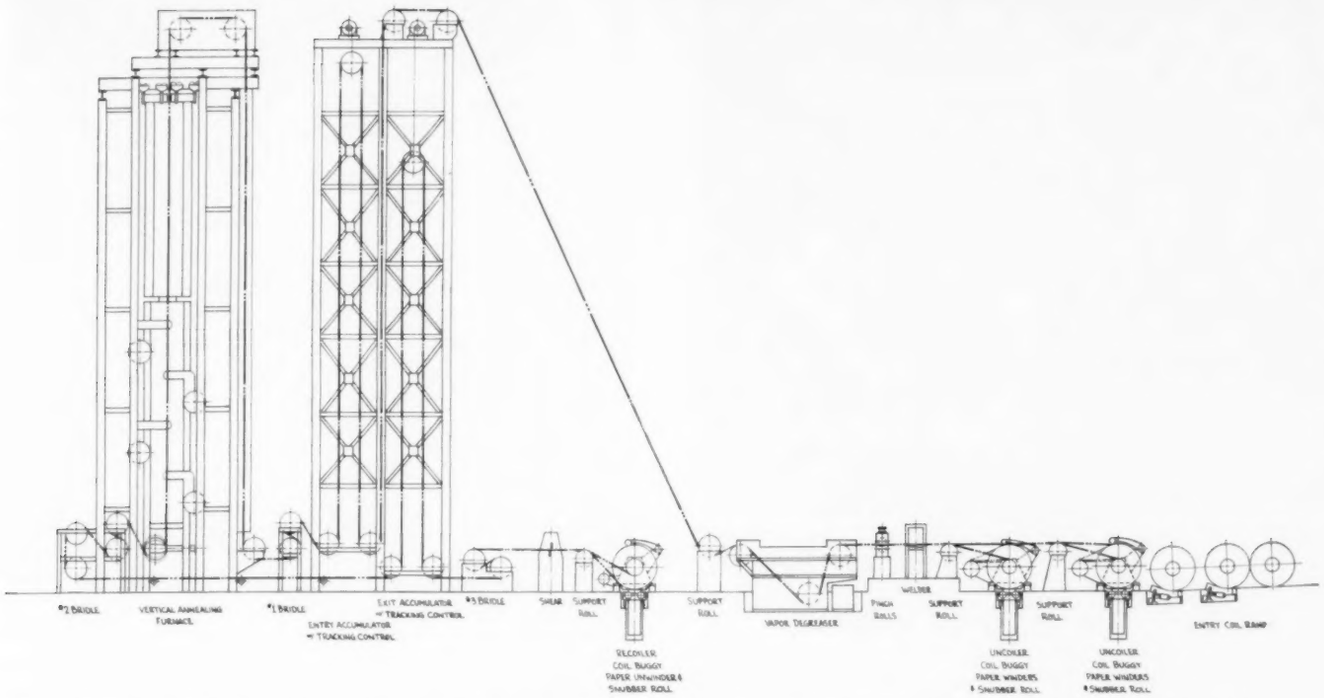


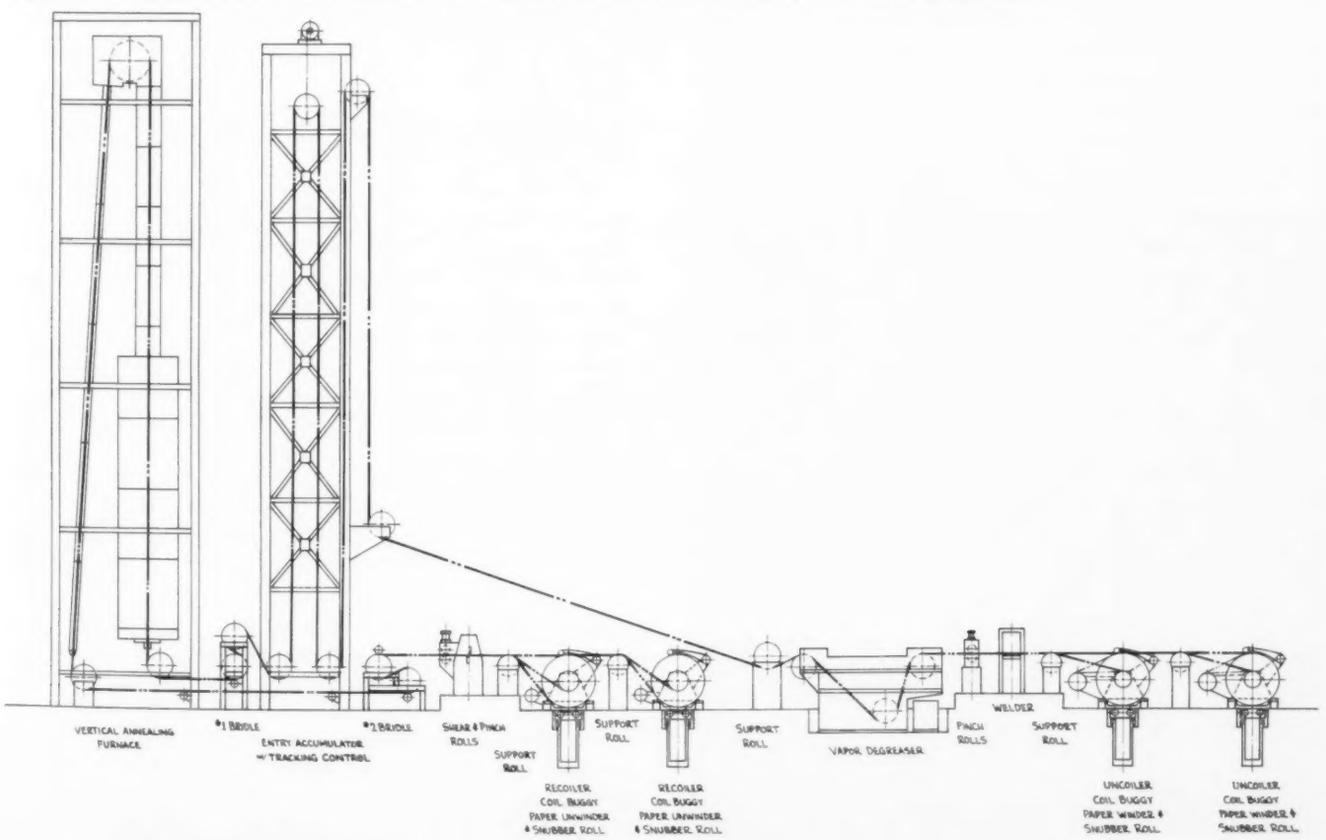
Figure 2 — Use of the double-back annealing line and one recoiler permits placement of the looping towers and furnace structure at one end of the building to simplify line servicing.

coiling equipment at the opposite end. Figure 2 illustrates a double-back installation which allows the quite tall furnace and accumulator tower structure to be located at one end of the building, thus providing easy crane access to both uncoiling and recoiling ends of the line and a simple building modification. Figure 3 illustrates this same line with a second recoiler which eliminates the exit accumulator. In order to more clearly illustrate the annealing process it may be of interest to review the general method of operation.

OPERATION

On a typical bright annealing line, coils are loaded onto the entry end coil buggies by means of a fork

Figure 3 — Installation of two recoilers eliminates the necessity of having an exit looping tower.



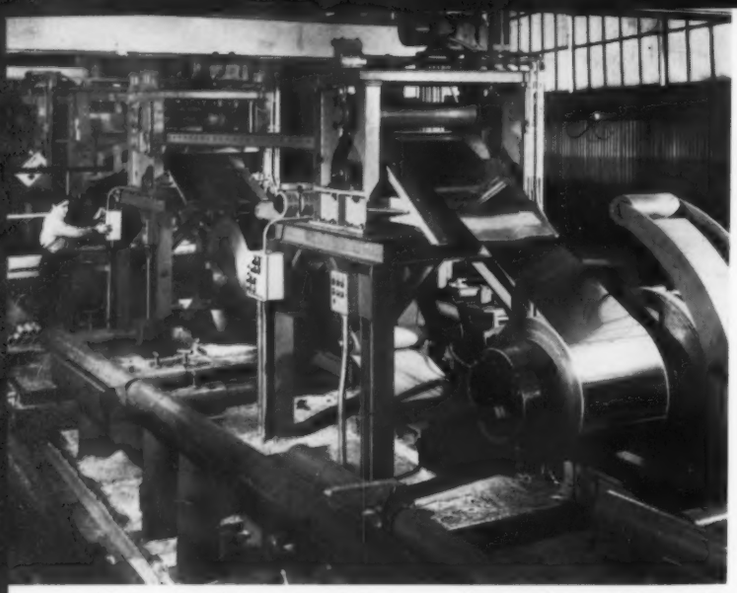
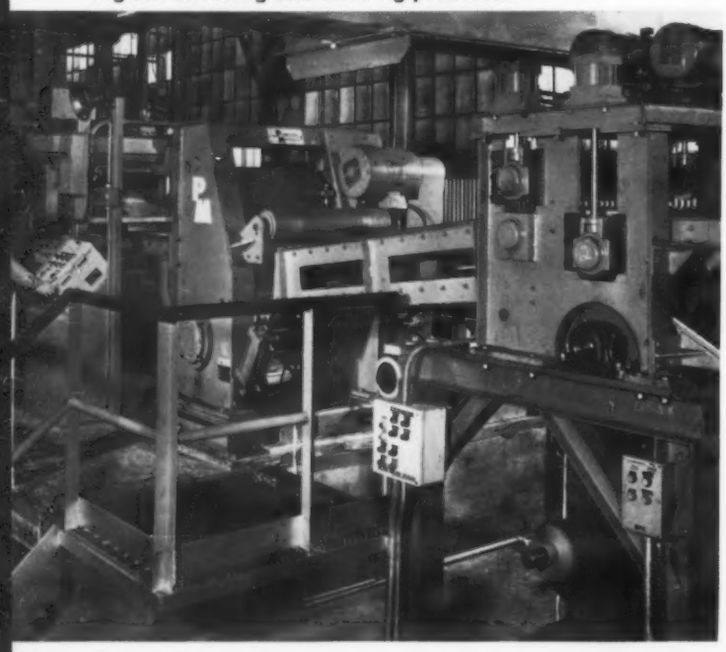


Figure 4 — The use of two uncoilers reduces strip entry delay time.

truck or overhead crane or may be received from a coil ramp. Each coil buggy consists of a heavy duty fabricated steel lift frame raised and lowered by a direct acting hydraulic cylinder. The coil buggy also travels laterally on rails by means of a hydraulic cylinder. The coils are then elevated and the coil buggy traverses forward loading the coil onto the uncoiler.

Two entry uncoilers (Figure 4) are provided, each equipped with a feed-up drive and mounted on a subbase for lateral adjustment of coil position. The two units are specified in order to permit loading of one coil and feeding-up of material ready for joining during line operation. This keeps the joining operation time to a minimum. The uncoiler head is hydraulically expanded to grip the inside wraps of the coil. The strip end is then fed forward to the crop shear utilizing the intermittent uncoiler feed-up drive. Paper winders, mounted on each uncoiler and driven by a-c torque motors, automatically take up the interleave paper from the coil as it pays off into the process.

Figure 5 — The strip is held in position by pinch rolls during the shearing and welding processes.



In order to cut heavy or damaged coil ends from the material entering in the line, a crop shear is supplied. The shear is a high-speed shear of the flywheel and clutch type to minimize crop time.

The line continues to run until the preceding coil has been depleted. At this point, the entry end of the line is stopped and the trailing end of the strip cut by means of the crop shear.

A welder is provided which will join succeeding ends of material utilizing a minimum overlap. The type generally proposed is a travel head wheel-type series welder which provides a minimum weld time and control of the total number of welds. During the welding procedure the line process section continues to run at line speed withdrawing material from an entry strip accumulator.

The entry end of the line is controlled by means of a set of entry pinch rolls (Figure 5) or an S-type bridle driven by a d-c motor. This unit serves to uncoil material by pulling from the entry reel and will also stop the entry end of the line during welding.

After welding the strip passes through a cleaner to remove the surface oil and grease in order to obtain a bright finish strip. The cleaner is either a vapor degreasing system utilizing a trichlorethylene solution, or an alkaline scrubber unit utilizing a water solution of alkali and detergent and a mechanical brush scrubber, followed by a rinse and dry section. The strip condition as it leaves the furnace is dependent upon maintaining a low dew point in the furnace atmosphere, and even the slightest amount of water entrapped in the weld and pores of the material can be detrimental. It is extremely difficult to obtain an absolutely dry surface with a scrubber unit utilizing a water base solution. In the trichlorethylene system, the cleaning solution is completely evaporated by the time the strip leaves the degreaser. This system incorporates a cleaning cycle consisting of immersion in the hot solvent vapors followed by immersion in a warm solvent rinse, a final vapor spray rinse and a second vapor rinse and dry. The solvent is recirculated and in order to maintain its cleanliness, a solvent still system is provided.

The strip then passes into the entry end accumulator equipment which is provided to supply material storage compatible with the welder time cycle, allowing sufficient time to make the weld properly while the process or annealing section is in continuous operation. This consists of an upper moving carriage containing one or more rolls and a lower stationary roll system. The moving carriage (Figure 6) is operated by a winch drive system which controls the carriage position. It raises or lowers the carriage in accordance with the process requirements. In addition the drive also serves to maintain constant tension on the strand in the entry section. The drive system is rather critical and generally consists of a winch drum, gear reducer and constant torque drive of either the d-c or eddy current type.

Upon completion of the weld, the strip at the entry end of the line, pulled by the entry pinch roll, overspeeds by approximately 20 to 30 per cent to fill this accumulator. The elevating carriage in the accumulator automatically travels upward during this period to accommodate the incoming material. Upon reaching its full stall position, the accumulator drive signals the line's entry end to drop to process speed.

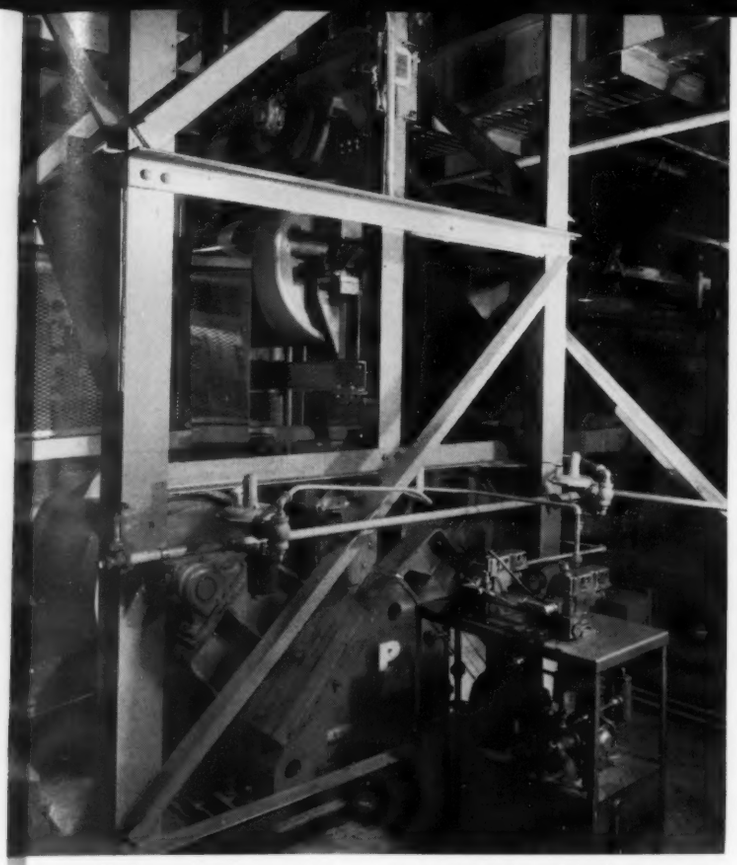


Figure 6 — The amount of strip stored in a looping tower is controlled by a winch drive system which raises or lowers the top roll carriage.

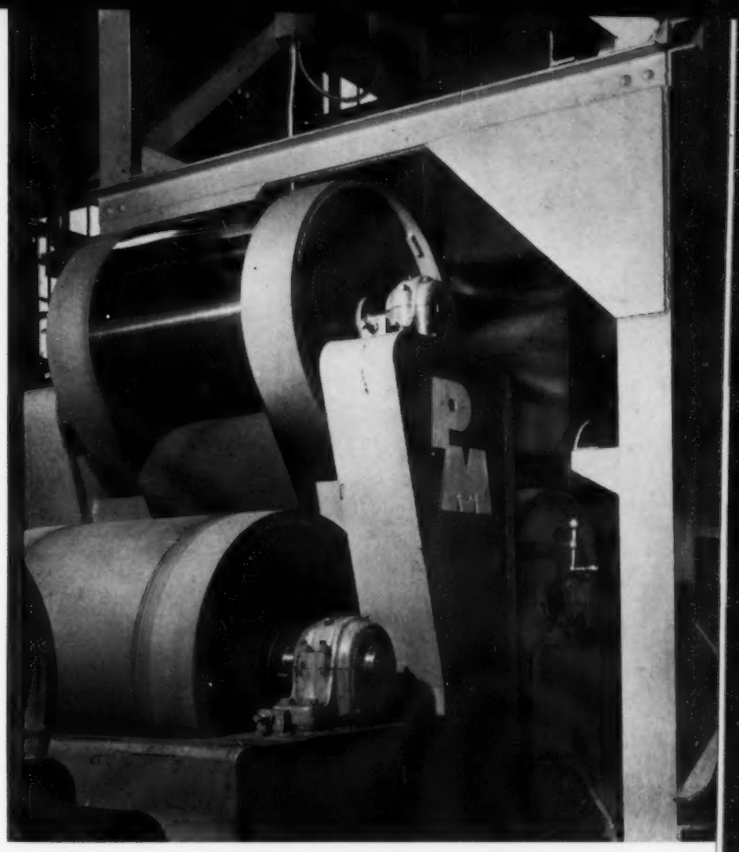


Figure 7 — Large diameter rubber covered rolls are dynamically balanced to prevent strip oscillation during operation.

Because there is a considerable amount of strip in the tower, generally of a gage where mechanical guiding is not practical, automatic guiding or tracking rolls are included, which are the entering and exit rolls in the lower section of the tower. Automatic tracking is provided by pivoting these rolls as determined by intelligence from an edge control system.

The moving upper carriage is incorporated in a separate structural steel framework, and it is equipped with a fail-safe braking system completely independent of the cable drive. In the event of excessive down speed, the self setting brake is energized.

From the accumulator the strip passes through an S-type bridle (Figure 7) prior to the furnace. The bridle has one roll driven by a d-c motor coupled to a completely enclosed gearbox. This bridle serves to pull material out of the tower and feed it into the furnace.

The material passes into the furnace, through a pressure seal which serves to retain the furnace atmosphere, upward over the top rolls and downward through the heating zone. After leaving the heating zone, it passes through a cooling zone system and out through the bottom furnace seal in an annealed and cooled condition. The temperature of the strip upon leaving the cooling zone is approximately 200 F.

An adjustable constant-tension roll arrangement is used to control the material as it leaves the furnace. This furnace roll provides a constant tension on the strand and may be preloaded to maintain the required strip tension.

The roll is pivot mounted and counterbalanced by air cylinders which allow it to move in approximately a vertical direction. The air pressure for this counterbalance is adjustable in order to control the total strip tension of the furnace, which is extremely critical since the allowable tension on a stainless strip at annealing temperature is approximately 500 psi of strip cross section. Of the total stress, approximately one half is added by the weight of the strip. Therefore, a tension adjustment system is used which incorporates settings for total tension and will maintain it within 0.5 per cent of the full scale reading or about 1.5 psi. The motion of the tension roll is translated into a speed function in order to maintain the proper relationship between the bridles on each side of the furnace, which are controlled by position changes of the tension roll.

Upon leaving the furnace, the strip passes through a second bridle similar to that at the entry end of the line and then into the exit strip accumulator, which is similar to the entry unit. The roll carriage normally operates in the depleted position and serves to take up strip, allowing the processing line to run continuously during the time when the exit end of the line is stopped for shearing out of the weld. Here again, when the accumulator tower operates in the full position, a considerable amount of strip is involved. As in the entry accumulator, the two lower rolls on the entering and leaving side are each equipped with an automatic tracking arrangement to maintain strip position automatically without any mechanical contact on the strip edges.

The strip passes out of the exit accumulator into the main tension bridle (Figure 8) which is also an S-type unit. This tension bridle serves to pull material out of the exit strip accumulator when in the full position and also provides back tension for winding a tight coil on the recoiler.

The material then passes through an exit shear (Figure 9) similar to the entry unit which is utilized to

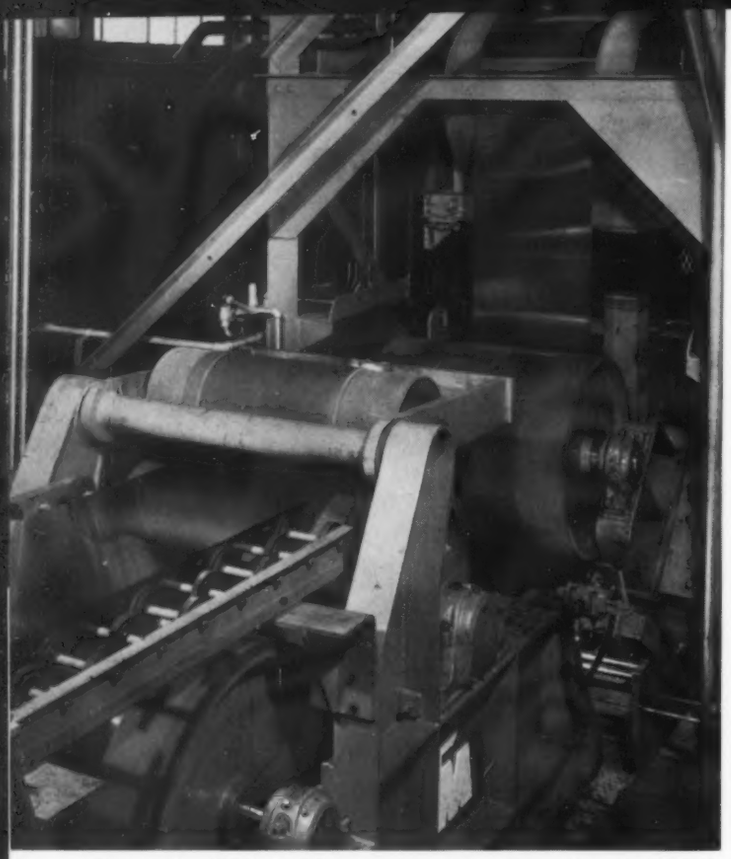


Figure 8 — Back tension, necessary to permit rewinding of a tight coil, is supplied by the main roll bridle.

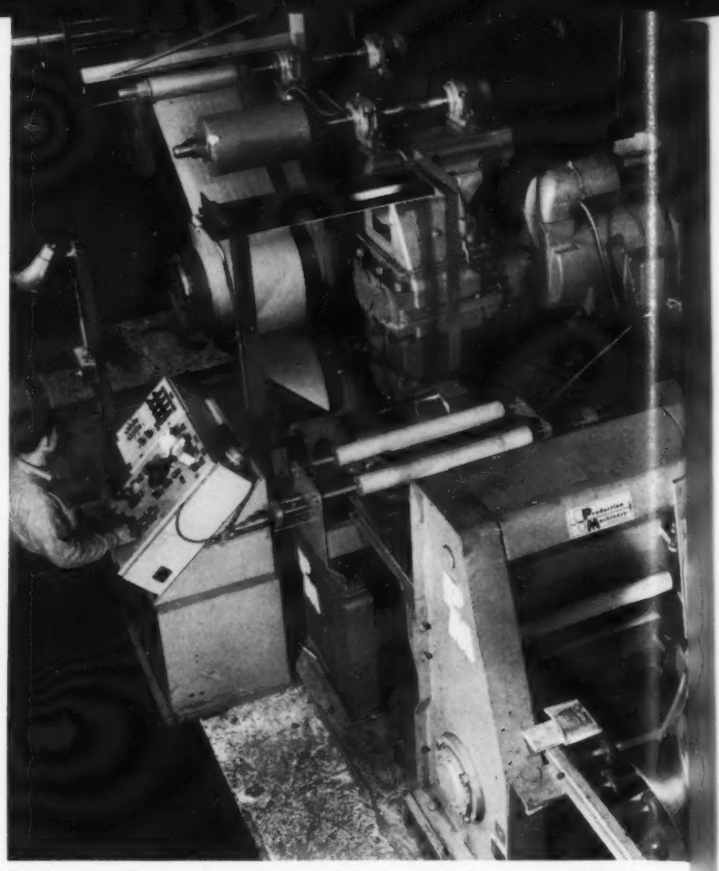


Figure 9 — Protection of the bright surface is accomplished by paper interleaving.

remove the weld from the strand.

The strip is rewound onto a recoiling unit which is driven by a d-c motor and winds a tight coil by pulling tension against the main tension bridle. The recoiler (Figure 10) is mounted on a sub-base for lateral adjustment of coil position, which is regulated by means of an automatic edge control system. In accordance with the intelligence received from a sensing nozzle, the recoiler adjusts its position automatically. The recoiler discharges the completed coil by means of a direct acting hydraulic stripper, onto a coil unloading buggy. The coil buggy lift is elevated in a position under the coil and the coil removed from the reel head. The coil is lowered by means of the hydraulic lift cylinder for removal by overhead crane or other material handling equipment.

Upon removal of the completed coil, the recoiler is ready for line operation, and the next strand is entered into the reel head. At this point, the exit end will overspeed depleting the exit accumulator and returning it to normal operating position.

As illustrated in Figure 3, the exit accumulator system can be eliminated by the addition of the second recoiler. In this arrangement, after the weld is cropped out, the strip overpasses the No. 1 recoiler and is entered into the second recoiler. This method has the advantage of reducing the number of material bends to a minimum after annealing of the strip.

In addition to the mechanical handling equipment described for the general line operation, a self-supporting furnace structure is required with both the gas-fired muffle furnace and the electric resistance heated type. Furnace access is required at several points for both maintenance and inspection. In order to fulfill this requirement, a fabricated steel structure is erected surrounding the furnace. This structure incorporates

TABLE I
Existing Bright Annealing Lines

Company	Strip width, in.	Maximum strip thickness, in.	Line speed, fpm	Heating method	Furnace construction
Allegheny Ludlum Steel Corp.	24	0.040	100	Electric	Open resistance elements
American Steel & Wire Div., United States Steel Corp.	37	0.060	150	Electric	Open resistance elements
Republic Steel Corp.	26	0.060	100	Gas	Alloy muffle
Sharon Steel Corp.	27	0.060	120	Electric	Open resistance elements
Somers Brass Co., Inc.	24	0.035	30	Gas	Alloy muffle
Wallingford Steel Co.	24	0.040	100	Electric	Open resistance elements
Washington Steel Corp.	50	0.109	100	Electric	Open resistance elements
Atlas Steels, Ltd.	18	0.060	60	Electric	Open resistance elements

the entry and exit strip accumulators and is equipped with access floors at suitable levels. Usually the structure is equipped with an elevator, to move personnel and material as required for maintenance, as well as a jib crane.

STRIP TENSIONS

In general the lines are designed to establish strip tension as follows: in the entry and exit accumulator sections, a strip tension of approximately 1200 psi is provided. In the furnace section, a total strip tension including weight of material in the vertical leg is approximately 500 psi maximum. In order to wind a tight self-supporting coil, a strip tension of approximately 2500 to 5000 psi is maintained at the recoiler.

CURRENT INSTALLATIONS

There are presently eight vertical and three horizontal bright annealing furnaces either installed or on order. Two of the vertical furnaces are gas-fired muffle type units, one heating on the upleg and another heating on the downleg. Six units of the electric resistance heated type are presently installed or on order. The widest line is for 50-in. material of 0.109-in. maximum gage.

Limitations of width and gage are primarily those set by the furnace design, with gage limited by the configuration and ability of the material to bend over the top furnace roll. Width is controlled by the builder's ability to produce a furnace in the width indicated.

The vertical furnace annealing systems presently operating or in the installation process, together with their physical characteristics, are shown in Table I.

The furnace operating characteristics will vary slightly due to furnace construction, limitations of muffle temperature on gas-fired systems and length of heating and cooling zones. Table II is typical of an electric resistance heated system.

TABLE II
Electric Heated Furnace, Temperatures

Strip thickness, in.	300 Series, 1950 F strip temperature		400 Series, 1550 F strip temperature	
	Furnace temperature, F	Strip speed, fpm	Furnace temperature, F	Strip speed, fpm
0.010	2300	98	1900	115
0.020	2300	48	1900	56
0.035	2300	31	1900	36
0.060	2300	16	1900	19

ELECTRICAL EQUIPMENT

Electrical requirements for bright annealing line installations are generally accepted as variable voltage d-c sources with separate power units for the entry end, process section and exit end of the line. In effect, the three sections can operate independently in accordance with their functional requirements.

EQUIPMENT COSTS

Approximate equipment costs for the bright annealing line described previously would be $700,000 to $750,000 for equipment plus $275,000 to $320,000 for foundations and installation, exclusive of the building or building modifications. These costs are approximate and representative of the requirements for a 24-in. wide, 6000-lb per hr capacity line having a range and thickness of 0.005 to 0.060 in., in coil weights of 20,000 lb and line speeds from 50 to 150 fpm.

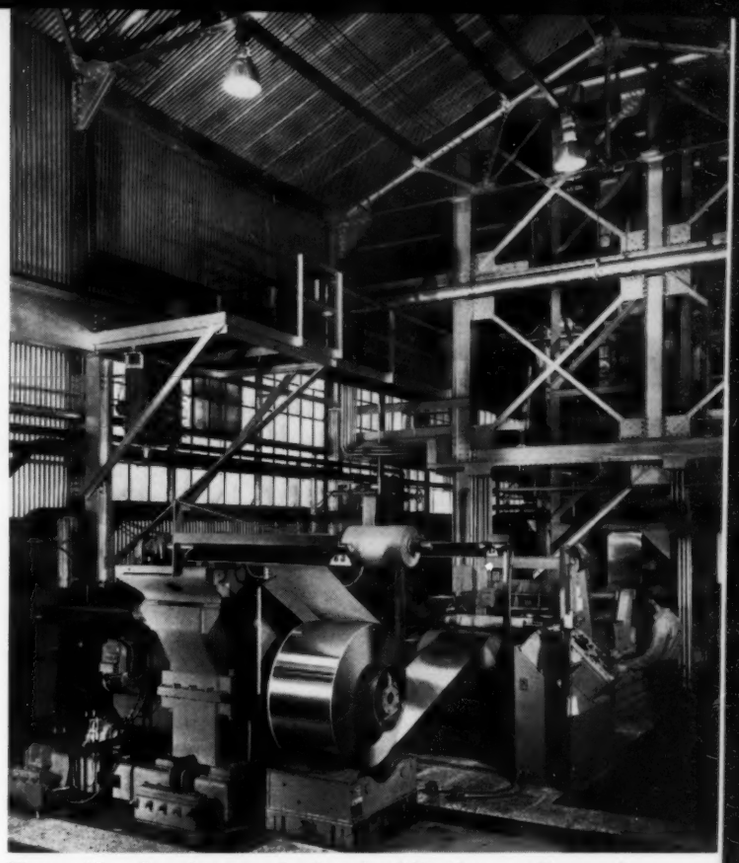


Figure 10 — Sensing nozzle signals shift the recoiler position during processing to permit winding of a straight side coil.

Bright annealing represents another step in the development of brighter and more corrosion resistant stainless.

While the initial impetus has been due to automotive demand for type 430 stainless, the processing by bright annealing also offers advantages for types 200 and 300 stainless, for the process may be utilized to reduce the buffing or polishing previously required on these grades.

An additional advantage not usually considered in the choice of bright annealing for all grades of stainless is the elimination of acid treatment. The cost of waste pickle liquor neutralization and disposal may range up to 3¢ per gal. A stainless processing line discharging its tanks twice monthly may run 20,000 gal total discharged acid including both sulphuric and nitric. These costs may run to $7200 yearly.

The neutralization of waste pickle liquor is extremely expensive, and largely unsatisfactory with present processes so that the complete elimination of acid scale removal is very advantageous.

When the reduction in cost by elimination of buffing labor and the elimination of acid pickling and waste pickle liquor are taken into consideration, the over-all economics of bright annealing becomes more attractive.

While it is still too early for an evaluation of operating costs, bright annealing is without question a promising step forward in the production of a higher quality product. ▲

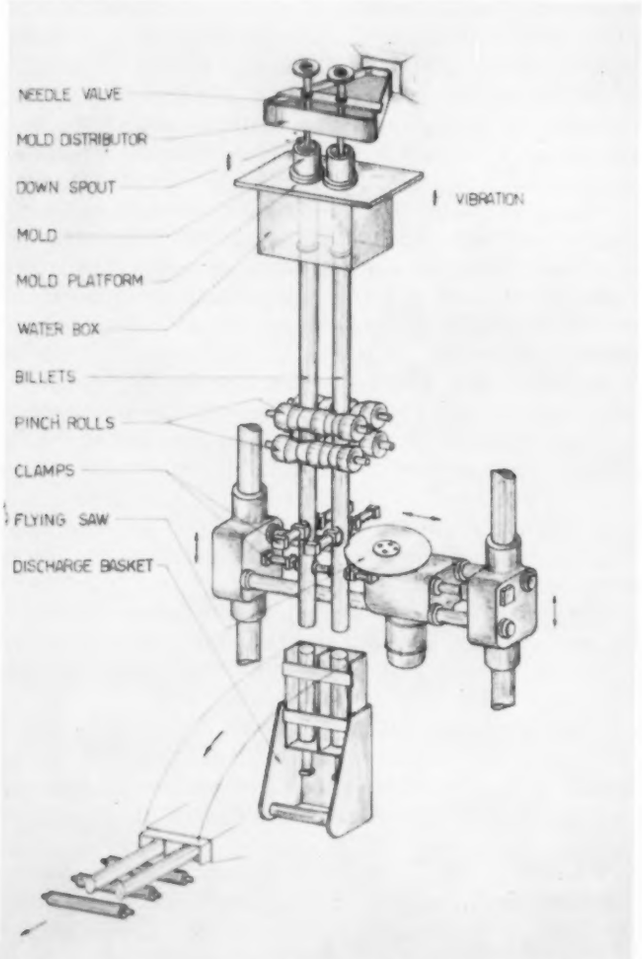
AUTOMATION

THE development of continuous casting was originally spurred on by a desire for improved quality of casting and the need of producing a variety of sizes and shapes made necessary by the advent of modern presses and rolling mills. Today's great interest in continuous casting processes however is due to the necessity for ever increasing efficiency and reduction of costs which must be achieved in order to maintain a competitive position in industry. After having taken its due course through the various production and assembly departments, automation is finally reaching the casting shop through continuous casting.

Before considering the topic further, it is necessary to clarify the terminology which one hears as soon as continuous casting is mentioned: continuous casting, D-C casting, tandem casting, semi-continuous casting. What are the correct definitions? To begin with, the term D-C casting stands for direct chill and refers to the process in the course of which molten metal is poured through a short, water-cooled mold, is withdrawn through the bottom of the mold while the metal is replenished at the top end of the mold. In addition, some form of coolant spray is usually applied to the casting as it exits from the mold.

The terms continuous casting, semi-continuous casting and tandem casting all refer to the D-C method, the differentiation between them resting on the mechanical means by which they are achieved:

Figure 1 — Fully continuous casting requires a large and continuing supply of hot metal to maintain operating efficiencies.



In fully continuous casting (Figure 1) a casting is poured for an unlimited time, restrained only by the amount of molten metal available. In semi-continuous casting the mechanical features of the casting machine are limited to a certain maximum length of casting. In tandem casting a number of semi-continuous casting machines arranged in such a fashion as to permit casting for an unlimited time and without interruption are made use of, restricted once more only by the amount of melt available and thus achieving a fully continuous operation by semi-continuous methods.

These methods will be described in more detail, their outstanding features, advantages and drawbacks. Those factors which should influence the selection of the appropriate method for the automation of a given casting shop will be determined.

In any D-C process molten metal is introduced into the top portion of a short, water-cooled mold and withdrawn at the bottom. The introduction of molten metal is usually made by means of a launder-distributor which channels the molten metal from the furnace or ladle to a downspout or pouring tube. This tube is immersed into the liquid metal in the mold and in this manner a quiet, turbulence free "under-pouring" of the metal is achieved, see Figure 2. Impurities are usually retained by the valve cones which regulate the liquid metal flow through the downspouts. Very finely divided and light impurities such as oxides may be entrapped in the flowing metal, but with a proper pouring technique they rise to the top meniscus in the mold where they are accumulated. The same practice applies to any gaseous impurities which may be present in the metal when it reaches the mold.

In order to achieve a good surface quality and uniform structure in the casting, the mold is oscillated in a vertical plane. This oscillation helps in the lubrication of the mold interface and generally facilitates withdrawal of the casting from the mold.

In the fully continuous casting machine, a set of mechanically driven pinch rolls is located at a certain distance below the mold. These rolls support the weight of the casting and prevent it from falling out of the mold; at the same time they exert a steady, regulated downward pull on the casting. The speed with which these pinch rolls turn is the casting speed

FOR THE CASTING SHOP

by H. HENRY SINASON
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. . . . continuous casting methods can produce a wide variety of shapes and sizes with a substantial reduction in operating cost . . . .

which in turn is of course predetermined by the alloy characteristics of the metal being cast.

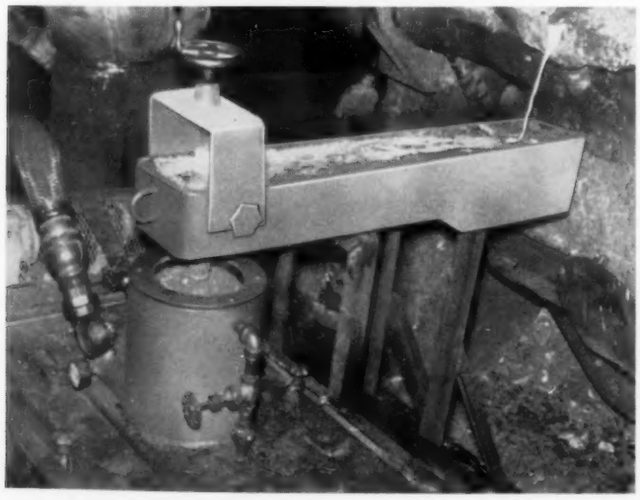
To start a cast in this type of machine, it is necessary to insert a long dummy block into the bottom of the mold in order to effect its closure. The bottom block must be long enough so that its other end reaches through the pinch rolls.

A flying saw is mounted a short distance below the pinch rolls. The saw works in conjunction with an automatic clamping device which grips the casting and then travels with it while the saw cut is being made. After the cut has been completed, the saw returns to its starting point while the casting is deposited in a discharge basket and automatically conveyed to storage. In the case of ferrous castings, the saw is replaced by a flying torch.

So much for a brief description of the mechanics of the fully continuous casting method. Now, what are its advantages and disadvantages and when is its use best indicated?

It is obvious that the fully continuous casting machine, especially when designed for the simultaneous casting of two or three strands, is a high production tool. It is difficult to cite exact figures since production rates vary with the cross section of the casting and the particular casting speed applicable to the alloy. This equipment is ideally suited to large production runs in one chosen alloy and cross section of casting. It will produce castings without any metal loss; gating and cropping are eliminated and only the chips produced from the saw cut are to be subtracted from the total yield.

Figure 2 — Immersion of the pouring tube in the mold permits splash-free metal additions to be made.



When using a fully continuous casting machine, the problem of quality control becomes simplified. Producing metal at a constant rate, with all variables remaining unchanged, the castings produced are of uniform quality, and it is sufficient to make spot checks at long intervals. Since this is a high production method, large batches of metal are cast in a relatively short period of time. This in turn eliminates many of the metallurgical probems which arise out of prolonged holding periods in a furnace: segregation, oxidation, gassing and abnormal grain growth are held to a minimum and simplify quality control.

Due to its high degree of automation, this method requires a minimum of labor. A single operator at the mold level supervises the entire operation from furnace tilt to automatic stacking of the ready cut castings. Complete synchronization of all intermediate steps is the reason for this saving in manpower. Add to this the reduced costs in maintenance and supervision which are necessary when casting is accomplished by means of

a large number of molds and furnaces, the elimination of the cost of operating separate sawing or cutting operations, and the elimination of the large inventory of molds which has to be carried, and it will be seen that there cannot be any argument against fully continuous casting from an efficiency and reduced cost point of view.

Like all apparently ideal solutions to a problem, there are certain factors which were taken for granted and which bear some observation. Designed as a high production tool, the fully continuous casting machine requires a vast and continuous metal supply. This kind of molten metal supply is usually available only in the plants of the prime metal producers, requiring as it does the type of furnace capacity associated only with the largest reverberatory, consumable arc or open hearth furnaces. This type of casting equipment does not function at its best when its production is frequently interrupted while waiting for batch furnaces to be readied and melts to be adjusted.

From the design of the equipment involved here, it can be seen that certain conditions of plant layout and material flow must be met if the operation is to be successful. The great height of the fully continuous casting machine requires a two story plant with the holding furnace or ladle located on the upper level. It is of course feasible to transfer metal from the lower floor to the upper level by means of ladles, but for obvious reasons this is not the most efficient method. To assure a smooth flow of the ready castings from the machine to the stacking area also requires a straight line layout if additional labor costs are to be avoided.

It was stated above that this type of equipment is ideally suited to long production runs in one particular alloy and cross-sectional area of casting. However, if the need arises for a variety of shapes and sizes in an assortment of alloys and metals, the fully continuous method shows a certain lack of flexibility. Due to the mechanical limitations inherent in the design features of pinch rolls and the flying saw mechanism, the range of sizes and shapes which can be accommodated on one fully continuous machine has its limits. Within these limits certain changes can be accomplished by appropriate design changes in the equipment, but there results a necessary complication of the equipment. Changing over from one size to another, from rounds to slabs, involves a readjustment of the synchronization mechanism, introduction of new dummy blocks, realinement of pinch rolls and resetting of saw stroke and travel. These operations must be performed carefully and are time consuming.

One of the deciding factors in choosing a new production method is always the cost of the original equipment. As can be seen and compared to the other methods of D-C casting, the cost of fully continuous casting equipment is high. If the production program and physical plant layout are suited for this type of equipment, there is no more economical casting method and the equipment usually pays for itself in a very short period of time.

To overcome some of the inflexibility which has been shown to be inherent in a fully continuous casting system, an alternate method was developed. It incorporates all those features which concern quality of

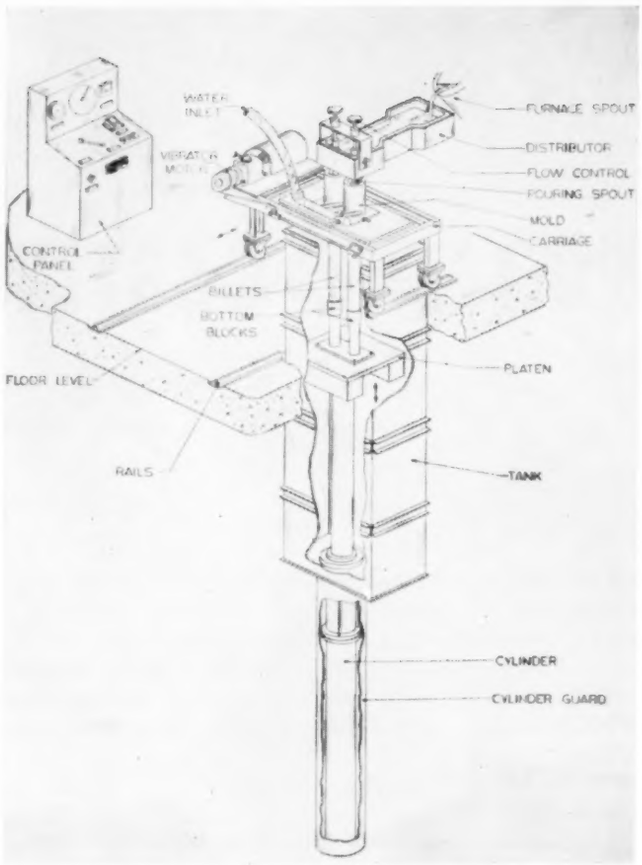


Figure 3 — Semi-continuous casting unit provides a single casting up to 30-ft long.

casting by adhering to the same mold and metal flow principle, but the mechanical features of the equipment operate by different means.

In a semi-continuous casting machine the dummy blocks which seal the bottom of the mold are rather short and are fastened by their other end to a platen, see Figure 3. This platen is connected to a hydraulic cylinder which operates with a fully adjustable vertical movement. The casting thus rests on the bottom blocks on the slowly descending platen and is assured of a slow, uniform withdrawal from the mold.

When the end of the cylinder stroke is reached casting must be interrupted. The entire top part of the machine which supports molds, cooling jackets and vibrator is mounted on a carriage which is now removed out of the way so that the castings may be ejected by a reversal of the cylinder stroke.

The greater part of this type of machine is situated below ground level in an excavation, only the carriage is above floor level bringing molds and pouring spouts to a short distance above floor level and in line with the furnace pouring spout.

It is easily seen that space requirement is held to a minimum in an installation of this type. Increased production is achieved with this machine not by an increase in floor area required, but by increasing the vertical stroke of the main cylinder, in other words: that part of the machine which is buried below ground. Castings up to 30-ft long are being produced by this method today, in multiple strands of up to eight simultaneous castings.

Since there is no need for a synchronization of the

drive mechanism in this machine, no long bottom blocks are involved and no flying saw, it becomes an easy matter to change from one size or shape of casting to another. A simple exchange of molds and bottom blocks is all that is involved, and it can be accomplished in a matter of minutes.

As pointed out casting must be interrupted when the machine has reached its full stroke, and the castings must then be removed from the machine. Although this represents downtime for the machine, this non-productive interval is again limited to only a few minutes. The machine is usually so designed as to have its capacity coincide with the holding furnace capacity. In this manner, the time used for the removal of the castings is also used for the transfer of molten metal to the holding furnace.

Casting in a semi-continuous casting machine may be an intermittent operation limited to one shift or even part of one shift. Start of a new cast is easy and uncomplicated, and requires no advance preparation or adjustments of the machine. After the castings are removed from the machine they are conveyed to a separate sawing or cutting installation. Here they are cut to final size and a small section of metal, usually about 2-in. thick, is cropped from both top and bottom end. These cropped ends contain the impurities which have accumulated in the mold during the cast. In a casting 25 to 30-ft long, one or two in. of cropping loss represent less than 1 per cent, and even that is not a true loss since it is channeled back into the melting furnace.

Productionwise, the semi-continuous casting machine may equal or even surpass the fully continuous machine when the former is designed for the casting of a number of multiple strands. However, the stress is on high production capacity over a short period of time, during the need for a fast conversion of a batch of molten metal into sound castings. Its principal advantage lies in its great adaptability from very short and small production runs to high production output. Machines of this type have been built small enough for laboratory and pilot-plant operations, while others are in continuous operation in the casting shops of the prime metal producers.

From a quality control standpoint, a semi-continuous casting setup requires more attention than a fully continuous system since it is a batch type of operation. Laborwise depending on the number of strands being cast simultaneously, the machine requires one or two operators. If the number of strands does not exceed four, one operator is usually sufficient but he requires assistance from a floor helper or crane operator at the time of casting removal. The cost of a semi-continuous casting machine is much less than that of a fully continuous machine, and although a separate sawing or cutting installation is required, the combined price of the two approximates only one half of the cost of the fully continuous system.

Figure 4 — Two semi-continuous casting machines can be grouped to provide a continuous process.

In considering automation of a casting shop, when all considerations point toward the choice of a fully continuous casting setup, an existing plant layout may make this choice impossible. In another case total production requirements may justify fully continuous casting, but a great variety of shapes and sizes would make this choice impractical. To meet situations such as these the concept of tandem casting has been developed.

Tandem casting is the combination of two or more semi-continuous casting machines arranged so that they may alternately be supplied with molten metal from the same furnace, see Figure 4. For example, two semi-continuous machines may be installed at right angle to each other in front of a furnace, the furnace spout being situated on the bisector of the angle. The distributor has its furnace end fixed on the same bisector line in front of the furnace spout, but its front end containing the metal pouring tubes may be swiveled from one machine to the other. While casting proceeds on one machine, finished castings may be removed from the other machine and vice versa.

With tandem casting a fully continuous casting method is achieved by the use of semi-continuous casting equipment. Not only is a more conventional one level plant layout and operation realized, but an extraordinary amount of flexibility is obtained. Thus one machine may be set up to cast rounds while the other casts slabs, or two different sizes of the same cross section may be produced simultaneously and from the same batch of metal.

Quality control characteristics here are the same as would apply to the fully continuous casting machine, while metal recovery is similar to that obtained from a semi-continuous operation. A tandem installation usually requires two operators and one helper in order to assure a smooth operation. Costwise, the tandem installation falls some where in between the fully and semi-continuous systems.

D-C casting in all its forms and applications is today common practice in the nonferrous field. Even those metals which had always been considered unsuitable for D-C casting either because of their crystal structure, their tendencies toward segregation and inverse segregation, hot-shortness, etc., are today being cast successfully. Notable in this respect are the new high tensile bronzes, the high temperature resisting nickel base alloys, some of the zinc alloys and magnesium and its alloys. In the ferrous field fully continuous casting has met with considerable success in Europe, and there is considerable evidence that the steel industry of the U.S.S.R. relies very heavily on

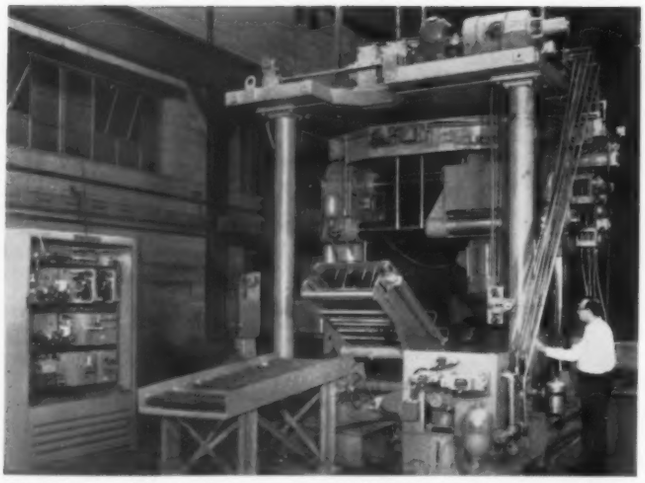


Figure 5 — Multiple strand continuous casting machines can produce various shapes and cross sections.

this method for a major part of its production. In semi-continuous casting the first machines for the production of the relatively small tonnages of special alloy steels, including the stainless series, are in the fabrication and near startup stages.

Concerning the shapes produced to date by the D-C method, one can confidently say that almost any basic geometric figure and cross section can be cast. Rounds, squares, rectangles, hexagons and octagons, parallelograms, triangles, pipes and hollows have been produced. And the D-C method is not limited to the integrated plant which requires castings for subsequent rolling, forging, extruding or drawing operations, see Figures 5 and 6. An interesting application, which shows the many possibilities offered by this process, was the case of a foundry which had to produce large quantities of a casting which later on was to be machined. The casting had an odd configuration, but one which could easily be inscribed in a parallelogram without having to cast too much excess metal. A semi-continuous casting machine was installed having two

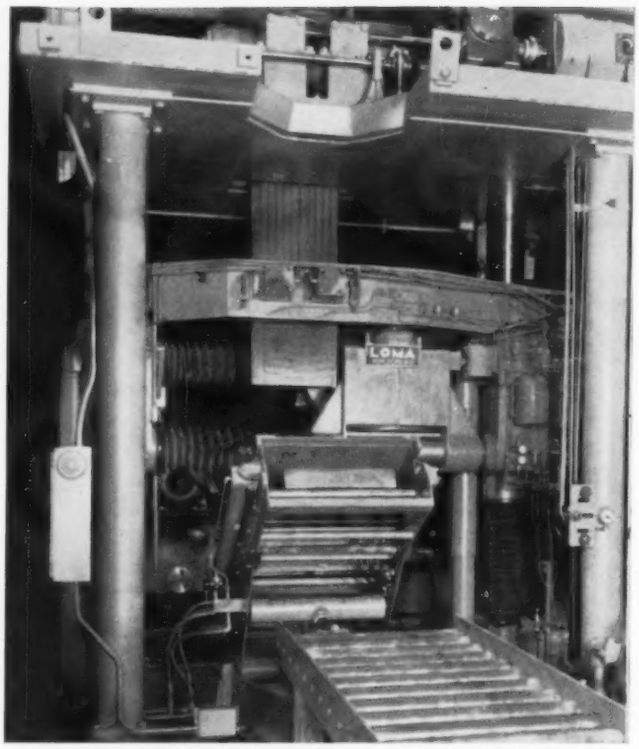


Figure 6 — Large slabs suitable for direct reduction can be produced by continuous casting.

molds in the shape of a parallelogram and with a stroke of 15 ft. The two long strands were subdivided and cut into required thickness after casting and then machined. The operation proved to be amazingly efficient. The metal saved by eliminating gating and risers, the cost reduction in avoiding cleaning and sand blasting and the elimination of rejects due to faulty castings, molds and porosity, as well as superior physical characteristics obtained by the D-C method opened an entirely new field for the application of this method to the manufacture of machine castings. ▲

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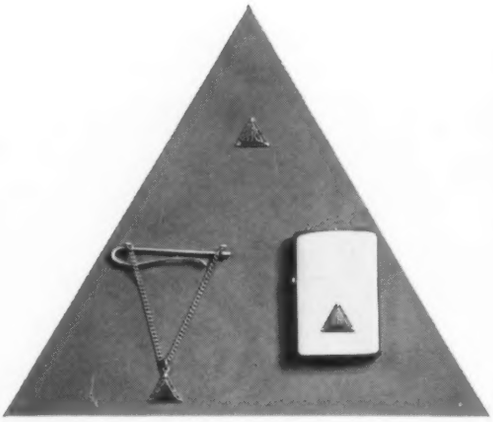

ASSOCIATION OF IRON AND STEEL ENGINEERS

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Hot Strip Mill Electrical System Design Trends

By W. M. KRUMMEL, Steel Mill Application Engineer,
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. . . . faster mills require faster gage control response times, which are accomplished through continuing system modifications and static switching applications . . .

THE increased activity in hot strip mill construction has focused considerable attention on the growing importance of flat products and the application of electrical equipment to improving product quality and decreasing product unit costs.

Flat products are sold in a highly competitive market; therefore, quality must be maintained or improved wherever possible and unit costs must be kept to the minimum.

A hot strip mill is a major investment for any steel plant: there is first the basic investment in land, excavation, foundations and buildings and then in equipment both mechanical and electrical. With the new mill there is always the problem of balancing the cost of additional horsepower and more automation equipment against expected gains in quality and lower unit costs.

A formula that must be examined by the planners for the new mill is:

More production equals more rolling work equals larger horsepower and higher speeds plus more automatic and more responsive equipment plus automated scheduling and production planning.

The plus factors in this equation represent increments in initial investment costs that will obtain for the producer higher utilization of over-all investment and facilities and will in turn achieve lowest unit production cost with maximum quality.

BASIC STAND DRIVE SYSTEMS

New hot strip mill drives are being supplied with rectifier power conversion for the main drives, supplanting the conventional synchronous motor-generator set. The chief reasons for this development have been lower equipment first cost, lower installation cost, higher operating efficiency and faster response.

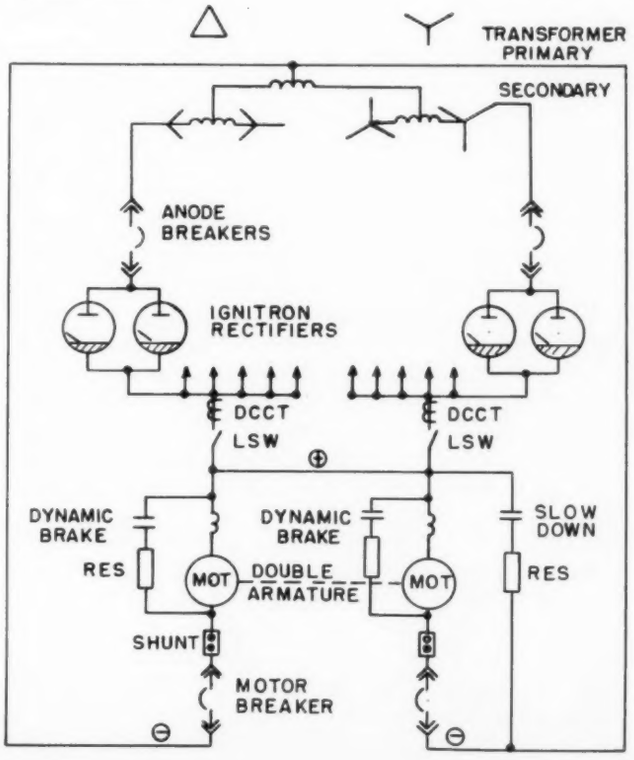
The motor-generator set is at present a more flexible arrangement from the operating viewpoint and with its other advantages as a source of leading kvar and its regenerating ability, there will be cases where it may be economically justified and its use considered.

STAND DRIVE ARMATURE CIRCUIT

New mills are being built with larger horsepower ratings per stand than ever before. We now are building 6000, 7000 and 8000-hp stand drives. In these sizes it frequently becomes more economical to use double-armature motors, and the rectifier power supply is usually made up of two units in parallel, see Figure 1. The double-armature motors will balance load without the aid of an equalizer bus or cross connected series fields.

High-speed anode breakers are used for protection against rectifier tank arc-backs and semi-high-speed motor breakers are used for protection against faults in the d-c system.

Figure 1 — Simplified typical d-c armature circuit. Larger drive ratings require double-armature motors with double rectifier units.



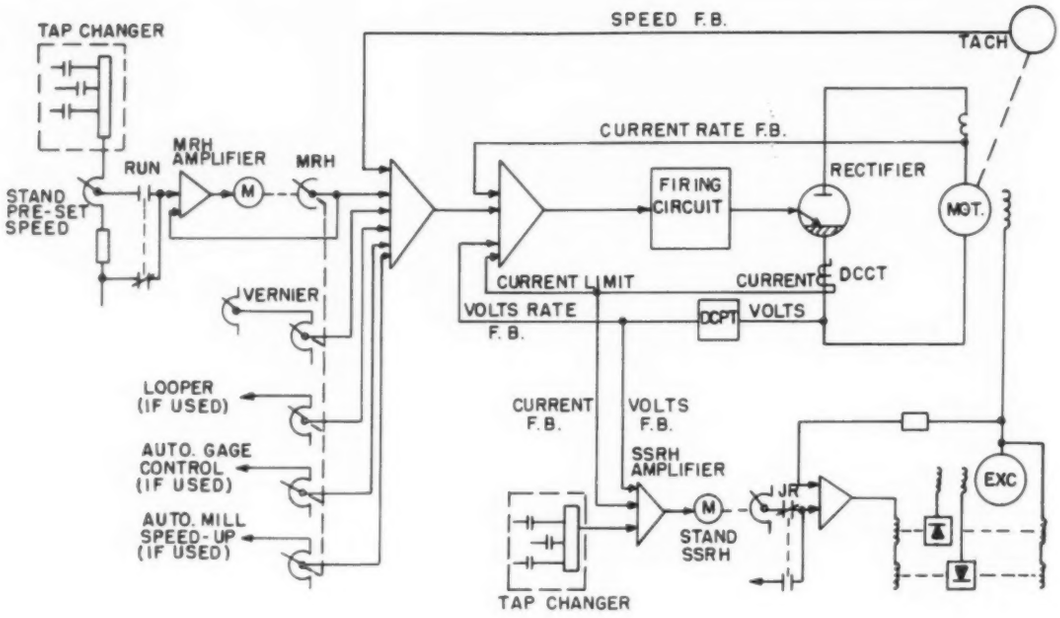


Figure 2 — Fast response is obtained through rectifier voltage regulator with new rectifier firing circuit. Slower motor field regulator follows to maintain steady-state armature voltage at desired operating level.

INDIVIDUAL STAND SPEED REGULATORS

One of the areas of greatest improvement in hot strip mill electrical equipment has been in the design of stand speed regulators. Speed regulators are now accepted as standard equipment for the hot mill.

A review of the benefits derived from speed regulators emphasizes that the fastest response and the most accurate control are required in order to provide:

1. Increased production and fuller utilization of the mill. By reducing the time required for setup and the time lost due to cobbles the mill is available for useful production a greater percentage of the time.
2. Increased production and improved quality from more uniform operation of the mill. The speed regulators permit more accurate setting of repetitive schedules and hence a more uniform product.
3. Reduction in the number of cobbles. The fast speed of response of the manual vernier controls greatly reduces the number of cobbles. Fewer cobbles result in reduced mechanical damage and increased productivity.
4. Less width deviation. A regulated mill will allow the strip to enter the stands much more smoothly. The stretching of the metal which would result from changes in interstand tension due to the impact speed drops and variations in motor regulation is virtually eliminated.

The new speed regulator obtains its fast response through rectifier voltage action, see Figure 2. A slower response regulator follows behind to maintain steady state armature voltage at the desired operating level by adjusting motor field current.

The greatly improved response of the speed regulator is largely made possible by the silicon-controlled-rectifier firing circuit developed for the pumpless ignitron rectifier. Previous firing circuits utilized a slower 3-phase power magnetic amplifier driving element. The new firing circuit requires a lower power input level permitting the application of transistor amplifiers in the voltage and speed comparison circuits rather than the larger and slower magnetic amplifier.

The new circuitry also provides much faster and sharper cutoff in current limit than heretofore.

Impact speed drop due to suddenly applied load and speed variations due to a-c voltage variations are improved by means of voltage rate stabilization.

Master speed control—The operator's speed adjustment is preset and limited to the range between base speed and top speed. The basic reference signal to the speed regulator is set by the master motor operated rheostat (MRH), a servo driven set of potentiometers. When the stand selector switch is turned to "run" the voltage set by the operator's rheostat is fed to the MRH servo amplifier.

If it is assumed that the speed called for by the operator is above base (or that speed set by the auto-transformer tap position), the drive will accelerate from standstill to full voltage at full motor field strength. When the motor speed reaches that corresponding to rated voltage the regulating system causes the motor field strength to be reduced until the preset speed is reached.

Vernier speed adjustment signal as well as looper and automatic gage control signals are applied to the input of the speed error amplifier. Each one of these signals is represented by an absolute voltage. These voltages must be recalibrated as a function of operating speed to give the same per cent range at any point in the operating speed range of the motor. For example, a looper height of 12 in. above normal pass line corresponds to some absolute voltage output from the looper position regulator, regardless of the operating speed of the motor. If this voltage is to give a certain per cent speed change at any operating speed, then it can be seen that this absolute voltage must be recalibrated as a function of the operating speed. Master motor operated rheostat dials are used to recalibrate these various signals.

New speed regulator design benefits—Basically then this system of speed control gives these desirable features:

1. Full torque for acceleration over the voltage range and constant accelerating rate over entire motor speed range resulting in minimum accelerating current, least kvar and least disturbance to the a-c power system.
2. Preset speed control allowing the drive to be shut

down and restarted with the drive returning to the same speed as before.

3. Ability of the operator to change speed from one known point to another by means of calibrated dial on the manual speed preset rheostat without holding onto a selector switch and watching a speed indicator as in previous mills.

MILL QUALITY AND PRODUCTION IMPROVEMENT

Many mill operators recognize the importance of good reheat furnace design and practice in obtaining quality slabs without skid marks. They also recognize the problem of maintaining heat in the slab entering the finishing mill in order to minimize thermal rundown. However, many of the problems in these areas have not yet been solved economically with mechanical equipment only. Good reheat furnace practice most often requires a slower production rate that may be tolerable for expensive alloy products, but the same rate is frequently intolerable for profitable production of low carbon products.

Recent experience with a production analyzer, or automatic gage logger, applied to an older hot strip mill showed that the operating crew with the highest tonnage rate turned out the poorest average quality product in terms of on gage, while the operating crew with the lowest tonnage rate turned out the higher quality product.

This points up the human failing of generally being able to provide either high quality work or high quantity work but not both at the same time.

It is possible to provide both quality and tonnage in the modern hot strip mill with the aid of increased automation. Automatic gage control, the new speed regulators and new computer techniques are available to the mills today.

AUTOMATIC GAGE CONTROL

The automatic gage control system for hot strip mills to be discussed is based upon the gagemeter principle which has been described previously.[1,2]* The fundamental relationship is $h = S_0 + (F/M)$ which simply states that with strip in the mill the loaded roll opening (h) is the sum of the unloaded roll opening (S_0) which is a result of screw movement, plus the spring in the mill housing (F/M). The spring in the mill housing is proportional to the roll separating force (F) and inversely proportional to the mill spring constant (M). The loaded roll opening (h) closely approximates the exit strip thickness. The value of S_0 is obtained from a potentiometer geared to the screw. The roll separating force (F) is obtained from the output of load cells which are most frequently located under the bottom backup roll chocks.

There have been two installations in 1960 of automatic gage control using the gagemeter and at least two more are scheduled for 1961.

Gagemeter-screw system—The pulpit operator has a set of decade pushbuttons which enable him to select the desired thickness (h) to be produced by the gage control stand. The signals representing the S_0 and F/M values are added and then compared with the reference signal as obtained from the operator's setting for desired output thickness. The difference or error signal is amplified and the output of the power stages of amplification is used to drive the stand screws. A movement of the screws will generally result in a change in interstand tension that will tend to oppose the gage corrective effect of the screw movement. It is then necessary to correct the gage control stand speed and preceding stand speeds so that interstand tension is constant during screw changes. This system encourages the use of constant tension holding loopers. If such loopers are not used then speed correction signals must be programmed into the stand speed regulator references as a function of screw movement. This system is referred to as a gagemeter-screw control, and this control is always used for the early stand or coarse control and is also to be preferred for the later stand or vernier control.

The chief characteristics of the gagemeter-screw system are then:

1. Requires holding constant interstand tension during screw changes.
2. Constant interstand tension results in gage correction with minimum if any, width deviation or necking of strip.
3. Enables control over more of the front and tail end of the strip.
4. Amount of gage correction limited only by shape requirements, roll force and drive horsepower limitations.

Gagemeter-tension system—The gagemeter also can be used in a system that corrects for gage deviation by adjusting interstand tensions. This system is called the gagemeter-tension system. Previous papers have reviewed the effect of changing strip tension to produce a change in delivered thickness.[1, 2] The recommended means of performing the correction is by adjusting the speeds of the gagemeter stand and the following stand. Loopers if used are maintained in a fixed position and behave as tensiometers, indicating and monitoring strip tensions to prevent excessive tension which would cause strip necking.

The advantages of the gagemeter-tension system are:

1. Economy in equipment cost in that screw movements by adjustable-voltage drives or electrohydraulic systems are not required.
2. Less effect upon shape than screw correction.

However, this system has important disadvantages:

1. The tension range, and thereby the correction ability, is limited to prevent necking when relatively large thickness deviations occur.
2. The correction ability is limited at the front end and tail end, and especially limited on correcting for the thickness increase at the tail end due to loss of tension. Strip must be in both stands on either side of the gagemeter stand for this system to have full automatic control.

Shape and grow-back—A few words about "shape" and "grow-back" may be appropriate here.

The term shape refers to the degree of flatness of the strip surface looking at a cross section of strip perpendicular to the direction of rolling. Work rolls are often ground with a slight convexity so that when under

* Numbers in parentheses refer to Bibliography at end of article.

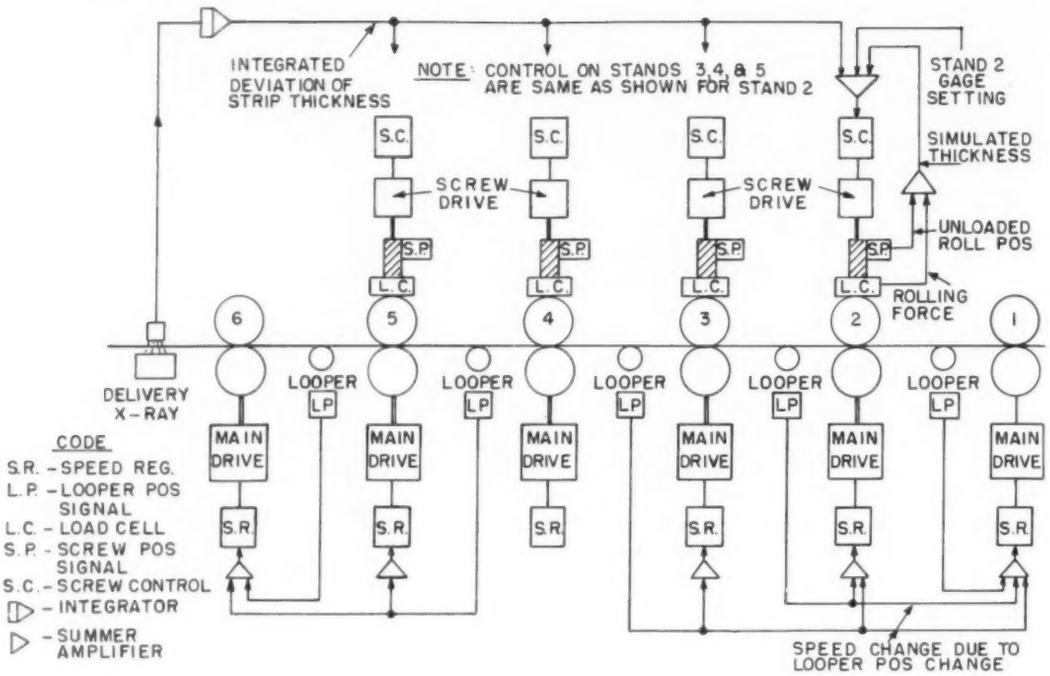


Figure 3 — Automatic gage control system has gagemeter screws on four intermediate stands of a 6-stand mill. Loopers are used to hold constant tension.

compression for a particular value of roll separating force they will give the strip the desired degree of surface flatness. In general, for a given rolling schedule the shape will vary if reduction is not held constant. With gage control on a mill stand the variation in reduction will be a function of gage deviation into the stand and will be much greater than if there were no gage control. This effect is often minimized by not using the last stand for gage control and instead allowing it to maintain a constant reduction. This is done in normal drafting practice with stand No. 6 taking a relatively light reduction.

The term grow-back refers to the reappearance in the later mill stands of thickness deviations in the strip resulting from hardness deviations. Thus in stand No. 2, for instance, one may reduce to zero all output gage deviation. However, if there are hardness variations in the strip due to skid marks or thermal rundown, these variations will cause thickness deviations to reappear in the stands following, if there is no gage control on these stands. This is an important fact when considering the work that has to be done by the vernier or later stand gage control. In a mill that uses loopers to hold constant interstand tensions the thickness deviations due to hardness deviations will be greater than in an unregulated tension mill. The work required of the so-called vernier gage control will be almost as severe as that of the coarse control. This is one of the reasons for preferring the screw system of correction as against the more limited tension system. This is also one of the considerations in recommending gage control on all intermediate mill stands.

There are several combinations possible using the two basic systems. These combinations will differ in their first cost and in their performance. The system shown in Figure 3 is the one for which superior performance is anticipated. There was one installed of this type in 1960, and another is scheduled for 1961.

The preferred system is gagemeter screws on all intermediate stands of the mill when used with conventional adjustable-voltage screw-down drives. An alternate, less expensive system might be gagemeter screws on stands No. 2 and 3 and gagemeter tension on stand No. 5, see Figure 4.

It is expected that this system will have the advantages of:

1. Minimum width deviation. An alternate pro-

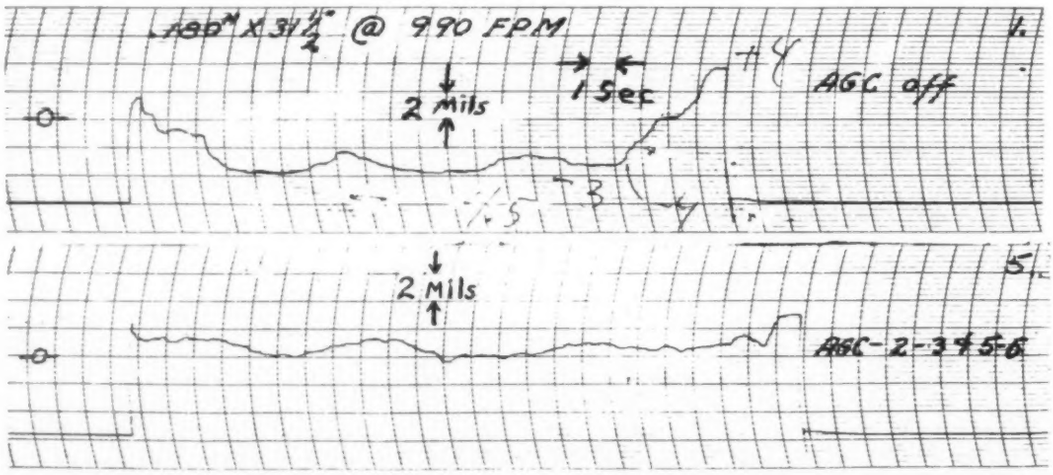


Figure 4 — Top oscillogram shows gage performance on hot strip mill without automatic gage control, bottom with automatic gage control, both for 0.180 x 31¼ in. System includes gagemeter screws on stands 2 and 3 and gagemeter tension on stand 5. Effect of coil ends is significant on chart coils.

posal with vernier gagemeter-tension system will have some width deviation, depending upon the grow-back in the mill of strip hardness variations.

2. More strip within tolerance on front end and tail end.

3. The all gagemeter-screw system is expected to hold closer tolerances for hardness deviations due to skid marks. Actually the superior performance in this respect of the all gagemeter-screw system is due to its greater ability to correct for hard spots that grow-back in the mill.

4. The all gagemeter-screw system is a simpler gage control system in the respect that the controls for all stands are basically the same, and the loopers, if used, are duplicate on all stands. The alternate system with gagemeter tension requires a different operation for the loopers at the gagemeter-tension stand.

5. The performance of both systems on thermal rundown are about equivalent.

6. The alternate scheme using tension correction will always be limited in its gage correction abilities by maximum and minimum tension limits.

X-ray gages in automatic gage control—In the simplified drawing of the mill with automatic gage control (Figure 3) it should be noted that there are two X-ray gages. The X-ray gage at the delivery of the mill is used to monitor the delivery strip thickness providing a check on the accuracy of the gagemeter systems. The gagemeter will be subject to certain drift errors that affect the term M representing the mill spring constant. These drift errors generally occur over long periods of time, several slab rolling times, and are due to heating or cooling of the mill stands and rolls, changes in bearing oil film thickness and roll wear. The delivery X-ray gage (Figure 5) integrates the thickness deviation for a portion of the length of the slab and if necessary inserts a proportional correction signal into the gagemeter of each stand.

An interstand X-ray gage is used for setup, calibrating and check-out purposes during mill startup and break-in. This gage is not needed for any control purpose but serves only as a means of indicating interstand strip thickness to check out the gagemeters. The problems associated with mounting the two components of the X-ray gage, the generator head and thedetect or head in the interstand area already crowded with machines are significant.

First, the gage heads must be protected and cooled; and gage throat clearance must not be excessive. It is desirable to locate the gage heads as close to the roll bite as possible in order to afford maximum protection from cobbles and also still keep the throat distance within limits. It then becomes impossible to remove the gage heads without shutting the mill down for an appreciable time. This is not an important disadvantage for the gagemeter system since, as noted, the interstand gage is required only for indication and setup.

However, this does emphasize the difficulties that would be encountered if a gage control scheme were to depend upon interstand gages for continuous thickness monitoring and correction. The risk of having the automatic gage control out of commission for long periods of time or of having unpredictable and costly mill shutdowns would be great.

Electrohydraulic gage control systems—Electrohydraulic screw systems have been in use for a few years with cold mill gage control at one steel company. By the term electrohydraulic is meant a system which uses hydraulics for the power supply for the prime actuator but which is controlled by electrical regulators. One of the first electrohydraulic systems for operating screws on a hot mill is now being built. This system is probably the largest in terms of the combination of maximum pressure and flow capabilities.

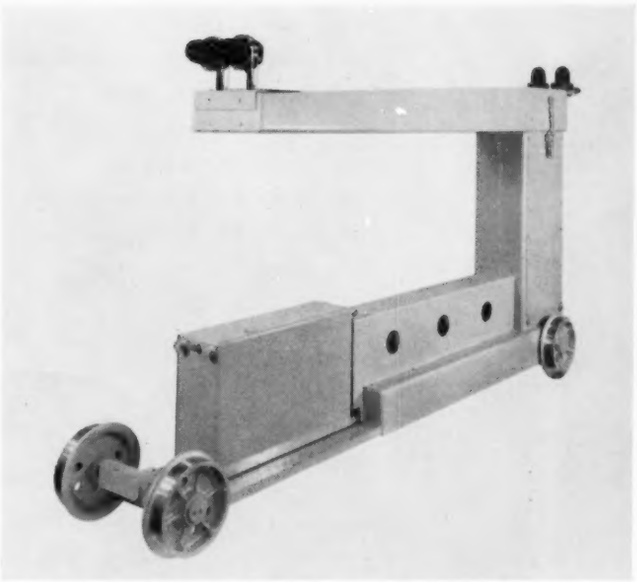


Figure 5 — Delivery X-ray gage is mounted on self-propelled carriage designed for hot mill service. The carriage is run on tracks and can be moved on and off the line with strip in the mill.

The advantages of the electrohydraulic system over an adjustable-voltage drive system for moving screws are much faster response, and much higher ratio of torque to inertia. The result is a drive system that is about three times more effective in making screw changes to correct for thickness deviations.

The output of the gagemeter amplifiers is fed to the electrically driven force motor coil of a high flow, fast response servo valve. This valve controls the flow of fluid into the main cylinder and thereby controls the position of the screws in response to the signal from the gagemeter control. The valve time constant is measured in milliseconds for small flow changes and short as it is, is still the longest time constant in the system.

It would be impractical to obtain the maximum required flow directly from a pump. A bank of accumulators is used to supply the cyclic high flow requirements, and a small pump stand is used to keep the accumulators charged up.

In designing the system (Figure 6) every effort has been made to keep all components as close to the main cylinder as possible. The servo valve is manifold mounted to the cylinder. The accumulators are grouped in line on a walkway platform leading to the stands. The pump stand is located on the mill floor up against the motor room wall line with the accumulator. This relatively compact arrangement is necessary in order to reduce head loss in piping, to keep the piping a reasonable size, and to avoid vibration and stability problems due to water hammer and traveling wave effects.

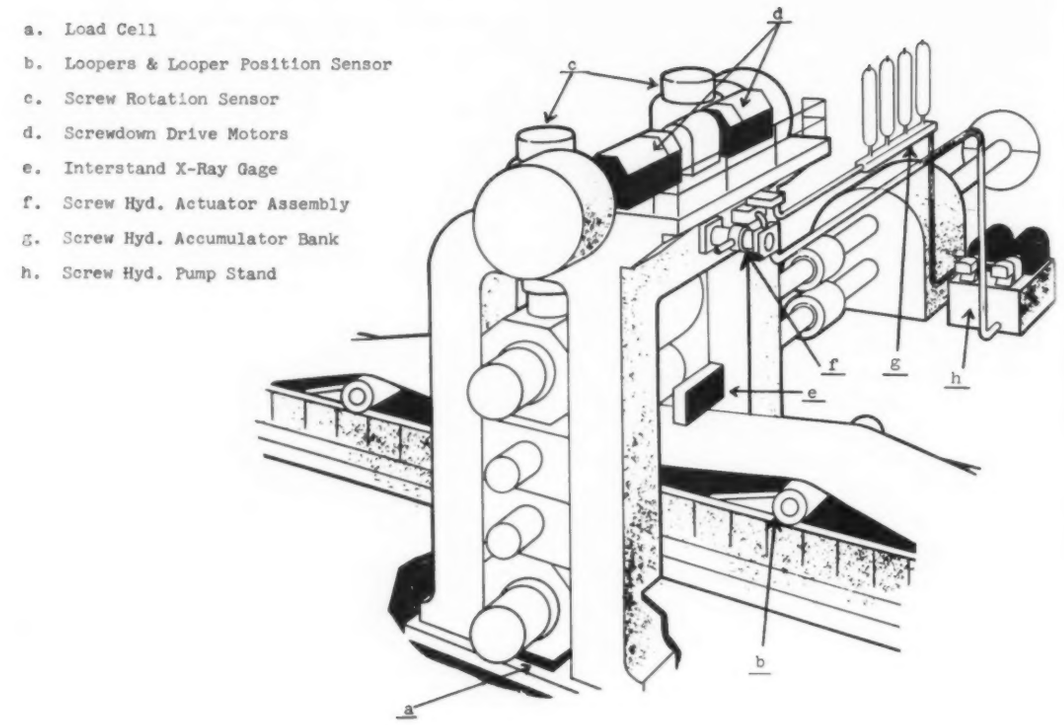


Figure 6 — Artist's illustration of the arrangement of gage control equipment on the mill housing.

It is expected that one stand equipped with this fast acting control will do the work of two stands equipped with adjustable-voltage screw drives. As a result, a recommended gage control configuration is gagemeter-electrohydraulic screws on stands No. 2 or 3 and on stand No. 5, rather than on all intermediate stands.

Loopers—Looper design has received considerable attention on the new mills. On past mills loopers have had many serious defects that prevented their satisfactory use for other than keeping the looping strip from folding over. The chief defects have been a slowness in movement and response and a wide variation in looper applied torque with looper angle above the pass line when holding constant strip tension. A new looper being built is hydraulic operated and is designed so that the ratio of looper cylinder force to strip tension is a constant independent of the looper position. With a suitable means for remotely setting looper tension and regulating looper cylinder force, such a looper is a great asset in operating and controlling the mill. When used to hold constant interstand tension, a position feedback unit is located at the looper pivot to provide a signal to either the preceding or succeeding stand drive speed regulators to keep the looper roll within its normal operating range. In effect the looper when used with this speed tie keeps the mill stands together without operator attention. The loopers can be used to hold constant low interstand tensions which will reduce width deviation and reduce the tail end gage increase resulting from loss of tension as the strip tail leaves the mill stands.

HIGH-SPEED STRIP ROLLING

New products being rolled on hot strip mills include very light gages for the automotive market. A problem in obtaining maximum tonnage with light gage product is to keep the front end of the strip on the runout tables at speeds over 1800 fpm. Many of the new 6 and 7-stand mills have delivery speed and horsepower capacity for rolling as high as 3000 fpm.

In order to utilize this capacity for rolling lighter gages a mill speed-up function has been added, which will permit the mill to run at a low enough entry speed to allow running the front end of the strip out to the downcoiler. At the instant the strip is snubbed on the mandrel the mill automatically accelerates to a higher speed, with as great as 25 per cent speed change in as little as five sec. The mill continues to roll at the higher speed until the tail end of the slab starts through and the stands are successively automatically dropped back down to entry speed.

In addition to increasing tonnage, other desirable results are obtained. Thermal rundown of the slab is reduced with shorter rolling time. Longer slabs can be rolled without exceeding the maximum allowable time for a slab in the mill.

The fast acceleration is made possible with the use of the new speed regulator and with fast acting loopers to hold the mill together.

Pumpback energy is absorbed by heavy resistors during the slowdown after the tail end of the strip leaves the mill stands. Slowdown resistor ratings are selected in accordance with the expected duty cycle and required rate of deceleration. The slowdown control is sensitive enough to provide quick response in the application of the slowdown contactor. Even though slowdown through 25 per cent of speed is required every slab, the value of the energy lost is still not sufficient to justify additional auxiliary regenerating equipment.

DATA LOGGING AND COMPUTER CONTROL

Advances in the application of computer-type equipment to on-the-line data logging and computer control of the mill have kept pace with these new drives and controls.

Production analyzer—The simplest equipment now in

use is the production analyzer, which is used to total for each coil rolled the total number of feet in each of several tolerance bands of undergage, overgage, underwidth and overwidth. The footage totals are printed out for each coil by an automatic typewriter and/or paper tape punch and/or card punch. This equipment is relatively simple consisting of digital counters, control logic, all completely transistorized and designed for heavy industry environments.

An equipment of this type has been just recently used on several hot strip mills to obtain data for mill performance evaluation. With these data, charts can easily be made up comparing the prime product output for the three turns, for different orders, for different days and weeks and even for different mills. Such data can be used as incentive for operating personnel, or for analysis by management in improving mill operations.

Hot strip mill data logger—However, users are not satisfied with logging only off gage and width, but are also interested in logging temperatures, charge and coil weights, sprays information, etc., in addition to identifying with considerable manual input information, each coil rolled. This information is required on a per coil basis.

It is necessary to add a memory capacity to the simple gage logger in order to log data for each coil at points distant from the X-ray gage. This raises the level of equipment complexity and cost.

When a tentative design is made for equipment to perform all this data logging it is found that the memory capacity and associated logic equipment and programming is capable of providing a simulation of the flow of slabs through the mill from the furnace to the coil scale. It then becomes very practical to consider the data logger as providing a "pacing" or tracking function, equivalent to the normal production order sheet routing, serving as a valuable check for the operators in their tallying of slabs and orders through the mill. Eventually such a system can replace the production order sheet routine.

In considering a system of this type the operator becomes a most important element. The operator must be responsible for inserting slab identification information into the beginning of the system when either charging slabs into the reheat furnaces or as they are discharged from the furnaces. The operator must also be responsible for notifying the system that a cobbled or reject slab has been removed from any one of several possible points in the process. These operator's manual inputs are simple pushbuttons and switches and can be arranged and interlocked with drive controls to a considerable extent to force the operator into remembering the prescribed routines. This will go a long way to ensuring the right thing is done at the right time. Nevertheless, no matter how much thought and time is spent on such routines, operator discipline is needed to make the system work.

Several mills are actively interested in such a system and it is reasonable to assume that the first hot strip mill data logger will be in operation sometime in 1962.

Computer control—On another yet higher level of automation, considerable progress has been made in the field of actual computer control of the hot strip mill, see Figure 7.

The system inputs basically are the incoming slab

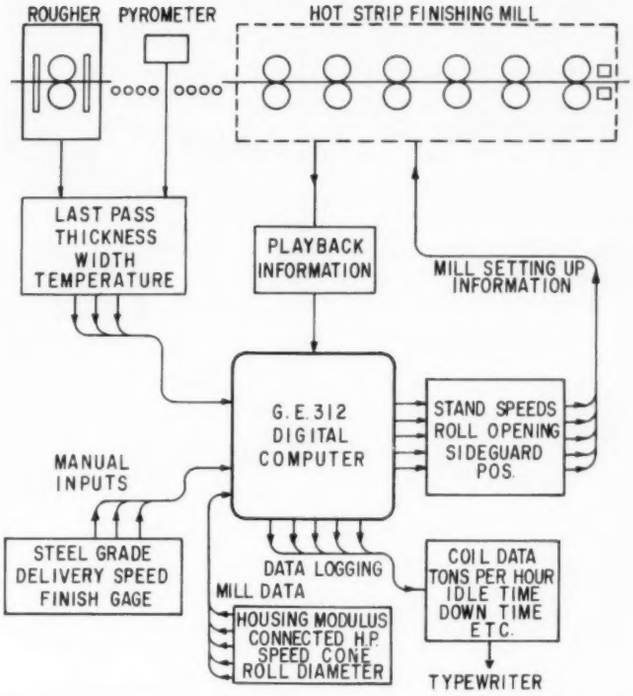


Figure 7 — Computer control system for a hot strip mill should increase production of quality strip.

thickness, width and temperature (automatic inputs), in addition to the grade of steel and desired delivery speed and gage (manual inputs). The computer makes the required calculations in accordance with a stored program to derive the optimum speed, screw setting and roll separating force for each stand. A simple operator's adjustment will modify the computer program to limit the load on any stand or stands as required to protect the mill. This function can also be used when necessary to "dummy" a stand. Another operator's adjustment allows for operation of the last stand at a constant draft, a common operating practice, to properly control shape. The computed roll separating force, speed and screw position settings are then used as the references to the gage control main drive and auxiliary drive regulating loops.

The computer control performs other minor functions concurrent with an automated system, such as automatic sideguard positioning, automatic setting of the X-ray gages (both interstand and delivery), and automatic setting of the delivery width gage.

As a by-product the computer system also performs data logging for production control and accounting functions. Data such as coil identification, footage total, footage off gage and footage off width are accumulated and typed out on a preprinted format. Accounting data such as calculated tonnage and downtime are assembled and typed out upon demand.

The results expected from this computer control are:

1. Increase in tonnage output by:
   (a) Decreasing cobbles. Cobbles are frequently the result of human error in setting up the mill and usually occur on the first slab in the mill.
   (b) Faster mill setup time.
   (c) More equitable distribution of load among all mill stands. Thus no single stand drive or

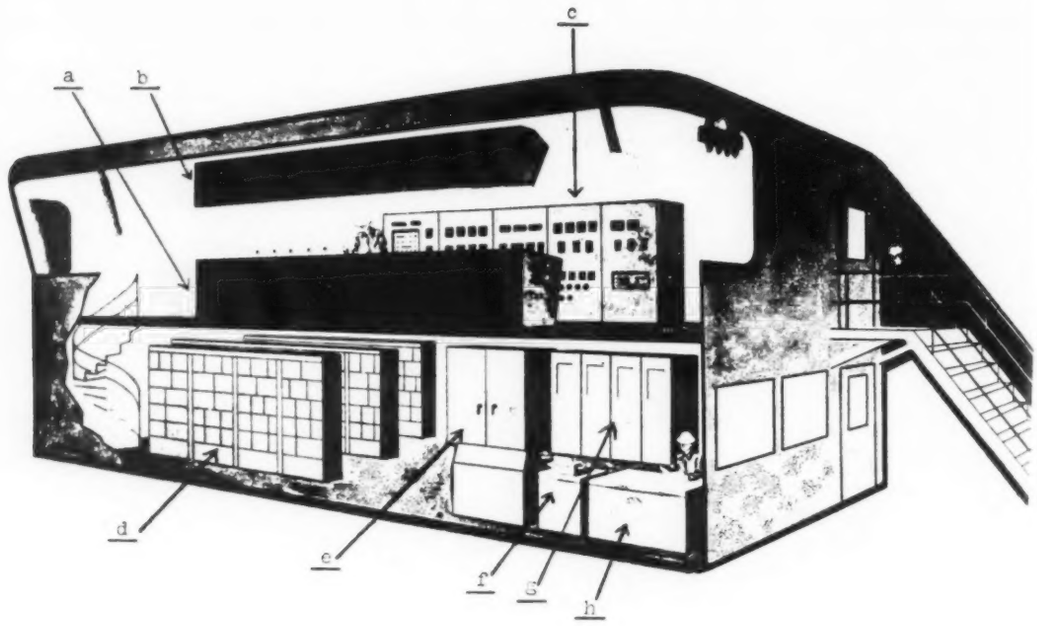


Figure 8 — The finishing mill pulpit should be designed for automatic mill operation.

a. Operator's Mill Control Desk
b. Operator's Overhead Meter Cabinet
c. Operator's "Set-up Device" Cabinets
d. Control Panels for Main Drive Regulators and Automation Functions
e. Computer Equipment Panel
f. Mill Data Readout Station
g. Mill Temperature Recorders
h. Mill Recorder's Office

section of the mill will become a "thermal bottleneck" to tonnage capacity.

2. Savings in operating expense by:
   (a) Possibly operating the mill with a smaller crew.
   (b) Using operators with less experience.
   (c) Eliminating manual record keeping.
3. Improvement in product quality by:
   (a) Controlled rolling practice. The mill is set up in a uniform manner so that the same product is rolled in the same and best way every time.
   (b) More complete production records and speedier availability of these records to management enables quick correction of problems affecting product quality.

MILL PULPIT DESIGN

The finishing mill speed pulpit has been expanded into a combination operator's pulpit, computer control room and supervisor or recorder's office (Figure 8).

On some of the new hot strip mills the transfer of much of the main drive control equipment has been made from the motor room to a special air conditioned computer control room located in close proximity to the finishing mill pulpit. The reasons for this location are chiefly the desirability of locating close to a present or future computer much of the control equipment associated with the computer, and secondly, to take advantage of the controlled ambient already being provided for the computer equipment. For a revamp, one user determined that it was less expensive in terms of cable and conduit to locate the new speed regulator and gage control equipment near the pulpit rather than in the motor room.

Considering the computer alone, there are more reasons for locating it on the operating side of the mill than in the motor room. The motor room itself is not the best place for computer type equipment. The noise and vibration can be very high, the possibility of stray electrical pickup from rectifiers and rotating electric machinery is great and the ambient may be subject to considerable variation. Locating the computer equipment in a special room on the operating side of the mill has the advantage of having mill data readout readily available to operators and supervision, permits shorter lead lengths to operator's numerous computer manual inputs, allows more isolated location from the vibrating and noisy machinery and a controlled ambient is readily obtained in a relatively small single-purpose room.

Once the main computer console and its input-output panel is located, then the location of a considerable amount of control equipment that provides input signals to the computer and in turn translate the computer commands into the setup and operation of the mill must be determined. Control equipment most closely associated with the computer are position regulators of screws and sideguides and the automatic gage control. It becomes a matter of convenience to put this equipment in the same room with the computer for easier setup and maintenance and of course advantage can be taken of the controlled ambient in the design of the control equipment. One step further and the main drive speed regulator equipment is in this room.

The design of the computer control room has been very satisfactorily taken care of by including it as part

of a 2-story prefabricated mill pulpit. In the top story is the operator's station. Behind the operator are setup cabinets and the load cell panels. In the first story are the control panels, and data logging and computer equipment. A mill recorder's office may be located here too, with temperature and other mill recording instruments and the output equipment of the data logger. An air conditioning and filtering unit is supplied for the entire pulpit. The range of temperatures considered comfortable for the operators is sufficient for the equipment. It is recommended that the walls of the pulpit structure be insulated.

While a computer may not initially be purchased, it is desirable to avoid an awkward and costly modification when a computer is added at a later date. Therefore it is recommended on all new hot strip mills that the pulpit computer control room be designed with adequate space available for the addition of future equipment.

SUMMARY

The basic pattern for the electrical system for hot strip mill finishing trains has changed greatly over the past few years and even within the last year. Individual stand power supplies with rectifiers are becoming commonplace. Stand speed regulators with fast response using static silicon controlled rectifier regulators are now standard equipment. Automatic gage control of one form or another is a must consideration for every mill, and standard equipment for most.

Management is today looking to data logging as an important means of obtaining closer control over the mill output. Each new mill should be planned with provision for computer control; if not a part of the basic equipment purchased with the mill, then it will surely be added very soon after installation. With increased experience with computer control will come more progress in the design of power supply, speed regulators and gage control and a continual upgrading of equipment in terms of accuracy, speed of response and reliability.

There are at least two apparent definite trends. One is the increase in automation reaching into all phases of the steel plant operation. With this increase will go greater complexity and scope of control and computer type equipment. The other is part of the electronics trend toward further miniaturization of equipment, replacement of rotating with static equipment and use of electronic techniques for all phases of the steel plant operation. The justification for these trends will be decreased unit costs and improved quality.

In this review of modern equipment for hot strip mills only the beginning of an accelerating rate of development for the future has been seen.

BIBLIOGRAPHY

1. "System Analysis and Design for Hot Strip Mill with Automatic Gage Control," by H. S. Maxwell and R. A. Phillips, 1960 Proceedings AISE, p. 503.
2. "New Techniques in Mill Control Gives Better Hot Strip," by R. J. Moran and H. N. Snively, January, 1961, *Iron and Steel Engineer*, p. 107. ▲

AISE DISTRICT SECTION SUMMER MEETING NOTICES

BIRMINGHAM SECTION

No June Meeting

BUFFALO SECTION

Tuesday, June 6, 1961
Golf Party
St. Catharine's Country Club, St. Catharine, Ontario, Canada

CANTON SECTION

Friday, August 4, 1961
Golf Party
Alliance Country Club, Alliance, Ohio

CHICAGO SECTION

Tuesday, June 6, 1961
Golf Party
Gary Country Club, Gary, Ind.

CLEVELAND SECTION

Thursday, August 10, 1961
Golf Party
Lakewood Country Club, Cleveland, Ohio

COLORADO & UTAH SECTIONS

June 16, 17, 18, 1961
Joint Meeting
Hotel Colorado, Glenwood Springs, Colo.

DETROIT SECTION

Tuesday, August 22, 1961
Golf Party
Grosse Isle Golf and Country Club

LOS ANGELES SECTION

No June Meeting

PHILADELPHIA SECTION

No June Meeting

PITTSBURGH SECTION

Monday, June 12, 1961
Golf Party
Fox Chapel Country Club, Pittsburgh, Pa.

ST. LOUIS SECTION

No June Meeting

SAN FRANCISCO SECTION

No June Meeting

YOUNGSTOWN SECTION

Thursday, June 15, 1961
Golf Party
Sharon Country Club, Sharon, Pa.

Pictorial Roundup

AISE Spring Meeting

Sheraton-Jefferson Hotel
St. Louis, Mo.
April 24, 25, 26

Rolling Mill Session members shown are (left to right); L. MacNaughton, A. A. Bradd, W. E. Dittrich, W. F. Hoffman, Dr. C. F. Zorowski, Dr. A. S. Weinstein, J. V. Latorre and Dr. K. N. Tong.

H. W. Dorset (third from left) meets with members of the Electrical Session; R. M. Sills, K. A. Petraske, J. F. Kostelac, R. M. Peeples and J. E. Reider.

Pre-session meeting is held by Rolling Mill Session members. Left to right are F. G. Kredel, A. J. Beck, J. F. Fox, Dr. M. D. Stone, J. F. Tepolt and C. H. Wexler.

Combustion Session members included (seated); F. E. Waterman, W. M. Bloom, C. W. Dunn; (standing) W. A. Greene, C. G. Bigelow and W. H. Kirwan.

Breakfast for authors and chairmen brought this group of Rolling Mill Session members together. Left to right are J. H. Russell, G. M. Esler, J. L. Dawson, Jack Binns and W. F. Hinkle.

R. A. Wilson, B. J. Sexauer, S. W. Stouffer and J. P. Wettach were members of the Mechanical Session.

J. V. Latorre (extreme right) takes part in a post-session discussion on roll spalling and breakage.

J. F. Fox (left) presented paper, "The Sendzimir Mill for Thin Tin Plate." (Right) "Operational Results of Automatic Gage Control on a Hot Strip Mill" was presented by Thomas Harmon, Jr.

Empty seats were at a premium for the off-the-record Rolling Mill Panel Discussion.

Shown at reception for speakers' table guests are N. P. Veeder, chairman of the board and president, Granite City Steel Co.; C. E. Pritchard, AISE president, and W. M. Akin, president, Laclede Steel Co., and guest speaker.

B. W. Hyde, superintendent-service and maintenance, Laclede Steel Co., chats with Carl Lohr, AISE St. Louis district secretary.

Approximately 250 registrants and guests attended the informal stag banquet.

I. N. Tull, past president AISE, chats with A. A. Boyle, vice president, Operations, Laclede Steel Co. and L. F. Gulley, vice president in charge of operations, Granite City Steel Co.

Blast Furnace Operations

by J. W. CARLSON, Superintendent,
Blast Furnace Dept., The Colorado Fuel and Iron Corp., Pueblo, Colo.

The basic operating concepts of the blast furnace are being carefully examined in an attempt to further operations improvement

THE blast furnace is the most practical way of winning iron from its ores. There are many methods in the laboratory of obtaining iron from the ores, but up to this time there has been very little commercial application of these methods because their product costs more than the metal from the blast furnace. Most iron ores are oxides; the iron is combined with oxygen, similar to rust.

The blast furnace department is the oldest metal-producing unit of the Pueblo plant of The Colorado Fuel and Iron Corp. The first furnace began operation in 1881. Since then, seven furnaces have been built; but only four exist today. Four-furnace production is about 85,000 to 90,000 net tons of iron a month.

The first furnace started producing September 9, 1881. It was called Betsy, later No. 1, and was also C furnace. It was 75-ft high and had a hearth ID of 9 ft-8 in. The second furnace, called Mary, was built in 1889. The third furnace, B, was built in 1892. Each of these three furnaces produced 60 to 150 tons of pig iron per day. They were charged by hand, that is the materials were shoveled into carts, the carts were hoisted to the top of the furnace and the carts were wheeled to the desired position and dumped by hand.

In 1892 the Colorado Coal and Iron Co. was consolidated with the Colorado Fuel Co. to form the Colorado Fuel and Iron Co. The turn of the century saw a rapid expansion. A furnace was blown in September, 1901. Mary was torn down at the time to make room for D which was blown in November, 1902. E was blown in November, 1903, and F in April, 1907. C was torn down in 1915 because it was no longer economical to operate. B ran off and on during the first world war, but was completely dismantled in 1942. Of the seven blast furnaces once situated here, there are now only four. They are A, D, E and F. Only D and E are much the same structure as when they were originally built. They have been altered and enlarged somewhat and have had many linings. Old F was torn down in 1937: new F started producing in 1942. A was completely rebuilt in 1951. These four furnaces each make from 600 to 900 net tons of pig iron per day or 2700 to 3000 tons total. They are approximately 100-ft tall not counting the superstructure, and their hearth diameters range from 20 ft-6 in. to 21 ft-9 in. The inside walls of the furnaces are protected with 30 to 40 in. of high grade firebrick, and the bottoms are made of from 45 to 85 in. of carbon blocks, with several ft of firebrick under the carbon.

The necessity of increasing blast furnace production has occasioned the construction of several units within the blast furnace department which process the raw materials, dispose of the products and supply needed services to support the furnace operation. This article will follow the flow of materials, explain the process and describe the functions of the service units.

ORE PREPARATION PLANT

Placed in operation in 1943, the ore preparation plant is one of the first plants of its type to be built in this country. The purpose of this plant is to crush and screen size all blast furnace ores, to blend the coarse ore in ore-bedding piles and to agglomerate the fine ore by sintering.

The ore is crushed in three stages: (1) it is crushed to minus 6 in. in a jaw crusher; (2) it is further reduced to minus 2½ in. in standard cone crushers; and (3) it is reduced to the final size of minus one in. in short-head cone crushers. The crushed ore is then screened to remove the minus ⅜-in. fines for sintering, and the oversize (minus 1 in., plus ⅜ in.) is conveyed to the ore beds.

The bedding plant is essentially a large mixer wherein the coarse portion of the crushed and screened ore is blended to reduce chemical and physical variations. The ore is placed in the beds in horizontal layers by a traveling stacker, and it is reclaimed in a vertical plane by a reclaimer. A bed of ore is completely laid down before it is reclaimed for use in the blast furnaces. There are four beds in all; two beds are being laid down while two are being reclaimed. Each bed has a capacity of about 18,000 tons, and a pair of beds can supply the furnaces with a uniform grade of blended ore for from ten days to two weeks.

The crushing and screening system is flexible and is used for crushing miscellaneous materials such as ganister, limestone and dolomite. Fines from the limestone and dolomite are conveyed to the sintering plant and utilized in producing fluxed sinter.

The purpose of the sintering plant is to prepare the fine ore for use in the blast furnaces by agglomerating the fines into chunks of porous sinter. The fine ore is mixed with the right proportions of ground coke breeze, fine limestone, flue dust and water. The mixture is continuously fed onto a slowly moving endless chain of pallets. These pallets have bottoms made of 1-in. wide grate bars, with narrow openings between the bars to allow the downward passage of draft air. As the pallets

travel over a series of wind boxes, the coke breeze is ignited by a gas burner. The induced down-draft carries the ignition down through the 15-in. deep bed of material. The burning coke heats the ore to a temperature at which the small particles fuse together into a porous mass. Cakes of sinter drop from the machines and are broken into 6-in. chunks by toothed roll crushers. The sinter is water cooled and then conveyed to railroad cars for transportation to the blast furnace bins.

The over-all daily capacity of the ore preparation plant is:

6500 net tons of ore and miscellaneous materials unloaded.
3500 net tons of sinter produced.
2700 net tons of bedded ore reclaimed.

MATERIALS HANDLING

A great deal of raw materials must be handled to operate four blast furnaces. The normal amount of materials handled in 24 hr is:

Coke, net tons	2,100	(handled twice)	4,200
Ore, net tons	2,500	(handled four times)	10,000
Sinter, net tons	3,000	(handled four times)	12,000
Roll scale, net tons	200	(handled four times)	800
		Total, net tons	27,000
Air	250,000,000	cu ft (10,000 net tons)	
Water for cooling	25,000,000	gal (1,000 net tons)	
Products			
Iron, net tons			2,700 to 3,000
Slag, net tons			2,000
Gas, cu ft			300,000,000
Flue dust, tons			150

BLAST FURNACE OPERATIONS

Blast furnace ores contain about 50 per cent iron, present as iron oxides mixed with gangue (waste) minerals. The purpose of the blast furnace is to remove the oxygen from the iron oxides, to produce molten metallic iron and to separate the gangue as molten slag. The iron oxides are reduced to metallic iron by gases, mainly carbon monoxide, formed by the incomplete burning of coke. This burning also supplies the heat required to drive the reactions and melt the iron and slag. Slag is formed from the unreduced minerals in the ore and fluxes. The flux, usually limestone, is added to make the slag more fluid. Limestone also serves to attract sulphur to the slag, thus removing sulphur from the iron.

The raw materials for the blast furnaces include coke, limestone, blended ore, sinter and miscellaneous iron-bearing materials such as roll scale and scrap. The raw materials are unloaded into storage bins from standard gage railroad cars traveling over the tops of the bins. Skip loads of the materials are drawn from the bins in a definite charging sequence. Six to eight skips of materials constitute a charge, which might be made up of 15 tons of ore or sinter, six tons of coke, two tons of limestone and one ton of roll scale or scrap. A typical charging sequence is: ore-ore-ore-coke-coke-limestone-coke-coke. Sinter may be substituted for ore, and roll scale is charged with the limestone. The coke is drawn from the bins by an automatic screening and weighing system. All other materials are drawn into scale cars which weigh and transfer them to the skips. The skips carry loads of as much as six tons as they are hoisted up a steeply-inclined bridge to the top of the furnace.

At the top of the furnace the skips dump into a distributor, which drops the charge through two hoppers into the furnace without losing furnace gas. The cone-shaped bottom of the upper hopper is called the "small bell," and that of the lower hopper is called the "large bell." In order to minimize the effects of segregation of materials as they are dumped from the skips, the upper hopper rotates before the small bell dumps each skip load onto the large bell. After an entire charge has accumulated in the lower hopper, the small bell is held closed and the large bell dumps the material into the furnace.

The furnace is kept full at all times. A rod extending into the top of the furnace indicates the level of the stock. When the stockline has dropped far enough another complete charge is added. Each furnace consumes three to four charges per hr.

The blast furnace derives its name from the blast of hot air which is injected near the bottom of the furnace. Air is actually the highest-tonnage raw material required by the furnace. To produce one ton of iron, about 4½ tons of air are required; whereas 2.2 tons of ore, ¾ ton of coke and ⅓ ton of limestone are required. The air is forced into the furnace at the rate of 50,000 to 55,000 cfm, at pressures up to 23 psi, and at a temperature between 1000 and 1300 F. Steam-driven turboblowers supply the wind. The wind is heated by passing it through a brick checkerwork regenerator, called a hot-blast stove. There are four stoves per furnace: three stoves are being reheated by furnace gas while one stove is on wind. Each stove stays on wind for two hr and then is heated for six hr. This recovery of heat from the furnace top gas is a major factor in the efficiency of the modern blast furnace.

The most important factor contributing to the efficiency of the blast furnace is the countercurrent flow of hot reducing gases upward through the downward-moving stock. The gases heat and reduce the ore, and they calcine the limestone. The top gas leaves the furnace at a temperature of about 400 F, and it contains about 26 per cent carbon monoxide, giving it a heating value of 90 Btu per cu ft which is recovered in the hot-blast stoves and in the powerhouse boilers. For efficient operation it is important that the stock movement and the gas flow through the stock be uniform. That is why so much effort is put into the preparation of raw materials and the control of stock movement. The stock movement is carefully watched, and countermeasures are taken to eliminate irregularities. Periodically the furnace is "checked" by reducing the blast pressure, thus inducing a downward movement of the stock.

The furnace lines are designed to accommodate the volume of material as it moves through the various zones of the furnace. The stack has a slight outward taper to facilitate the movement of the expanding material. Directly beneath the stack, the bosh tapers inward as the materials melt and reduce in volume. From the bottom of the bosh the hearth extends straight down to the bottom of the furnace. Each section is lined with suitable refractories to resist wear in that particular zone. The stack and bosh are lined with firebrick, about

three-ft thick. The hearth is lined with carbon blocks. The bosh and hearth linings are protected from high temperatures by cooling members, through which water is circulated. Ordinarily the lining will last for five to seven years, while the furnace produces 1,500,000 to 2,000,000 tons of iron.

The entire furnace structure stands about 175-ft high. The inside of the furnace is about 90-ft high and 21-ft wide at the hearth. The stack, bosh and hearth are circular in cross section. Evenly spaced around the top of the hearth are 12 tuyères, through which the blast is admitted to the furnace. About 3½ ft below the tuyères is the cinder notch, through which slag is flushed. Another 3½ ft lower and about 90 degrees around the furnace from the cinder notch is the taphole, through which the iron is tapped. The bottom of the hearth is about 3½ ft below the taphole. These dimensions vary slightly from furnace to furnace.

As the iron and slag melt in the bosh, they flow to the bottom of the hearth. The slag forms a layer which floats on top the molten iron. About two hr after a cast the layer of slag reaches the cinder notch. Then the cinder notch is opened and slag is flushed out about every half hr until the furnace is cast again. Five or six times in 24 hr the taphole is drilled out to drain the iron and slag from the furnace. The iron, at about 2500 F, flows through refractory-lined runners to mixer ladles. The slag is skimmed from the iron, and it flows to slag pots which carry it to the slag dump. After the furnace has been drained the taphole is plugged with a tar and clay mixture. A typical cast will yield 150 tons of impure iron called pig iron or hot metal.

The hot metal is actually an alloy containing about 94 per cent iron, 4 per cent carbon, 1.25 per cent silicon, 0.50 per cent manganese, and 0.040 per cent sulphur. Most of the hot metal is taken in the molten state to the open hearths. Iron to be cast into pigs for the foundry or for sale is taken to the pig machine.

PIG MACHINE

There are two double-strand pig-casting machines. At each machine the molten iron is poured into a runner in which it splits and runs to the two strands. The cast iron molds in each strand are filled as they pass under the runner. As the molds move up an inclined ramp, the iron solidifies and then is cooled by water sprays. At the end of the machine the pigs drop from the molds into railroad cars; the molds return along the underside of the machine. A lime slurry is sprayed into the molds before they come up around the pouring end again. The machine making the 30-lb pigs handles one ton of iron per min, and the machine making 60-lb pigs casts 1½ tons per min.

MAINTENANCE

Although most of the rebuilding is done when a furnace is relined, a crew of riggers, millwrights, welders, pipefitters, electricians and oilers is required for normal maintenance. A track, operated in conjunction with the open hearth department, is used to lubricate and maintain the blast furnace rolling stock, such as ladle cars, slag pots and railroad cars.

FURNACE AUXILIARY EQUIPMENT

The auxiliary equipment for a blast furnace can cost as much or more than the furnace itself. This equipment includes raw materials bins and a scale car where these materials are weighed out and taken to the skip car. The two counter-balanced skips alternate in carrying the materials to the top of the furnace. At the bottom of the furnace are the slag cars and the pig iron cars. Gas mains carry the blast furnace gas from the top of the furnace to a dust catcher where the heavier and larger particles of dust settle out. More gas mains lead the partly clean gas to electric precipitators where the fine dust is removed. One third of the blast furnace gas goes to the stoves and two thirds to the powerhouse to be burned in the boilers to generate steam.

There are four stoves at each furnace which are filled with a checkerwork of open flues and bricks. The gas is burned in the stove around the bricks heating them to 2000 F. Then the air on its way to the furnace passes through one of the stoves to absorb some of this heat.

The steam from the powerhouse boilers is used two ways. It drives the turbines that generate the electricity for the mill, and it also powers the air compressor turbines for each furnace which force the air blast through the stoves and into the furnace.

It takes one foreman and eight or nine men to operate the furnace each shift. A total of 500 men are employed in the department. This includes the ore preparation plant, the pig casting machine and bottom house unit, the slag dump crew, mechanical crews, coke and ore bin crews and a labor pool.

The years since World War II have brought many ideas and improvements in blast furnace operations. Some of these are:

1. Adding oxygen to the air going into the furnace to increase the smelting rate. This will be done when an oxygen plant, which will be required as part of the new oxygen steelmaking furnaces, is installed.
2. Adding steam to the air going into the furnace. At the high temperature in the furnace the steam breaks down into its component parts of hydrogen and oxygen. The value of oxygen was just mentioned. Hydrogen is a strong reducing agent and helps reduce the ore to metallic iron.
3. Building up high pressures in the furnace which makes the chemical reactions take place faster.
4. Concentrating the ores by ridding them of most of the impurities, thus feeding the furnace a richer diet to increase production.
5. Better sizing of the feed to the furnace to make a more uniform mix of the raw materials, and also allow better gas flow through the materials.
6. Mixing of limestone in the ores at the sintering plant thus doing part of the work on the ore before it gets into the furnace.

In 1900 the blast furnace was considered a perfect piece of equipment. It changed little except for some increase in size until World War II. The increase in demand for pig iron during the war and the prosperity since then has caused engineers to take a close look at its basic operating concepts. With the result of these new ideas it is expected that the blast furnace will move forward rapidly during the next few years. ▲

The Influence of Preloading on Economy of Foundations at the New Midwest Steel Mill

by ELIO D'APPOLONIA, President, E. D'Appolonia Associates, Pittsburgh, Pa.
and L. A. FUGASSI, Chief Engineer, Midwest Steel Corp., Div. of National Steel Corp., Valparaiso, Ind.

. . . . by taking advantage of the natural preloading of the Midwest Steel plant site in prehistoric times, it was possible to make very appreciable savings in the foundations . . . . necessary for this was a thorough study and analysis of the subsurface area . . . .

MIDWEST Steel Corp. is taking shape and rising from the narrow, flat stretches of sand along the shore of Lake Michigan in Porter County, Ind. The site was not always flat. Indeed, the dunes that covered the narrow strip of land reached to heights 200 ft above the surface of Lake Michigan. Prior to 1929 when National Steel Corp. had acquired the land, mining had stripped the dunes from the site. The limits of the site on Figure 1, a portion of the U. S. Geological Survey Topographic Map for Porter, Ind., are defined roughly on the north by Lake Michigan, on the west by Ogden Dunes, on the south by New York Central Railroad, and on the east by the start of the high dunes just to the east of the flat land. The grade elevation for the mill is about 600 ft above sea level or 20 ft above the mean water level of Lake Michigan. With the exception of the narrow strip of land adjacent to Burns Ditch which connects the little Calumet river to Lake Michigan, the site prior to construction was relatively flat at approximately present grade elevation. The dunes along the Burns Ditch were in part natural and in part formed during the excavation of the ditch.

The dunes [1]* northeastward of Gary, Ind., as in the vicinity of Burns Ditch, are recent modifications of dunes that formed some 9000 years ago when Lake Chicago, the predecessor of Lake Michigan, had stabilized at about 25 ft above the present level of Lake Michigan, to build what is called in geology the Toleston beach. The Toleston dunes are high and are connected by low winding ridges of sand. A study of Figure 1 shows, as one might expect in a dune area, sharp slopes ascending abruptly from low swamps at elevation 600 to high pinnacles at elevations 700 and 800. The low-lying depressions between the connecting ridges are erratic in shape occupying areas from ½ to 20 acres. Many of the depressions are swampy. It would not be surprising to find buried in the sand beneath these depressions organic material mixed with silt.

Not knowing the location of buried swamps at the site, because of missing topographic maps, posed the major problem for the most economic construction of the foundations. Recognizing the importance of the original topography of the area, a careful search was made for the mining records and for the topography of the site prior to mining of the sand for the Columbian Exposition in Chicago. The search proved futile.

General geologic data concerning the Toleston dunes in the vicinity of Burns Ditch suggests that the dunes had a minimum height of 50 ft. Blanketing an area under such a layer and removing it many hundreds of years later would indeed produce a site, regardless of the nature of the soils, that is ideal for the construction of a steel mill. The certitude of this preloading cannot be taken for granted when one considers the topography of the low-lying depressions among the dunes as found just east and west of the site. It is conceivable that the dunes migrated and that the whole of the area had been preloaded by the shifting sands. However, such an assumption was untenable. Lacking reliable geologic

* Numbers in parentheses refer to Bibliography at end of article.

Figure 1 — The construction site was on a dune area, with many swampy depressions.

and topographic data it was necessary, in order to locate the mill on areas occupied by high dunes, to plan and to execute comprehensive subsurface exploration and soil testing programs to achieve the objective of maximum safety and economy of the foundations.

The subsurface exploration program was designed to locate buried organic deposits and lake sediments that accumulated in the low-lying depressions during the formation of the dunes. Where the organic deposits have not been preloaded, serious settlement with damage to foundations can occur. It was not arbitrarily decided nor deemed advisable to place the foundations on piles or caissons which would by-pass the organic material and rest on the underlying firm glacial deposits and lake sediments that had been preloaded by ice during the advance and retreat of glaciers.

The first phase of the subsurface exploration was a group of exploratory borings to establish the general nature of the soils. With development of the plant layout this was followed by more detailed borings in the regions of heavy machinery and column loads. With the unfolding of the extent, depth and thickness of the buried organic materials, probings, prior to the installation of the foundations, were made in those areas where organic deposits were found.

This type of subsurface exploration program coupled with a detailed study of the soil properties and its strength led to large savings in the construction of the foundations. It is estimated that approximately 6500 piles penetrating into the dense sands and stiff lake sediments underlying organic deposits would have been required. An estimated saving approaching one million dollars was realized with the elimination of pile or caisson foundations. Column loads and mill units are supported on spread footings and mat foundations designed for an average allowable soil pressure of 4500 lb per sq ft.

Settlement observations have been maintained on all footings and mat foundations from the time of excavation through to various stages of loading under dead weight of building and machinery. Approximately one year after the start of construction, foundations supporting their full dead load have undergone only negligible settlement which is associated with the recompression of the soils.

The foundation investigation showed, even with the lack of topographic data which would have made possible an estimate of the preloading of the area, that there was no need to by-pass the buried organic deposits with piles or similar type foundations and that the use of spread footings and mat foundations proved both safe and economical.

Even with detailed topographic maps of a region subjected to the preload of sand dunes, it would not be wise to assume that low depressed areas, most of which contain shallow swamp deposits, have been preloaded by shifting sand dunes. It is known that since the turn of the century sand has been eroded from some of the high areas and in other regions sand has been piled up to form higher dunes. The changes in topography have not been severe. The record of movements of the dunes have not been of sufficient time to clearly establish whether or not the dunes have migrated across the strip adjacent the Michigan shoreline and whether or not the whole of the strip some one mile in depth parallel to the shoreline has been preloaded. Therefore, it is necessary to explore the low-lying depressed regions which contain shallow swamp deposits.

Assuming that in the future much of the area along the south shore of Lake Michigan will be graded for industrial development to elevations between 600 and 620, it certainly would be prudent to carefully explore all areas where present topography lies below approximately elevation 650 ft. The removal of 30 to 50 ft of sand would assure preload pressures of 1.5 to 2.5 tons per sq ft which are adequate for most industrial development.

The principal advantages of topographic maps are the proper location of mill units to take advantage of the preloading and the accurate location of borings to evaluate the strength properties of soils underlying low depressed areas among the sand dunes. By properly correlating the topographic and geologic data, the lay-

out, depth and number of borings and soil testing can be planned to yield maximum information at minimum cost. In this manner full advantage can be taken of the strength and bearing capacity of the soils with substantial savings in construction costs.

DEPOSITION AND PRELOADING OF SOILS

The foundation investigation was directed to establish the limits of the mined sand dunes that had preloaded the mill site and the magnitude of this preloading.

Exploratory borings numbered from 1 to 20 in Figure 2 covered the site on approximately 1000-ft centers in a north to south, east to west grid pattern. Bedrock throughout the site varied rather uniformly between elevations 420 and 450. No deep buried channels were found. Over much of the area a dark gray shale overlies the predominant limestone formation. Figure 3 is a typical north to south section as one would see the soils looking west. This section extends from boring 110 north of the present shoreline to boring 39 some 1500 ft south of the Indiana Harbor Belt Railroad.

The silts and clays interspersed throughout the sand deposits have been formed from the shales which were removed, pulverized and redeposited by the glaciers. Dense to medium dense sand occurred, in general, from the ground surface to elevation 575. Between 575 and 540 there are organic deposits and lenticular lenses of clay, silt and sand. At elevation 565 in boring 5 is a lens of medium gravel. The two dashed lines sloping upward between elevations 565 and 590 indicate depths at which traces of gravel were found in the medium dense to dense sand. The lens and thin layers of gravel are old buried shorelines.

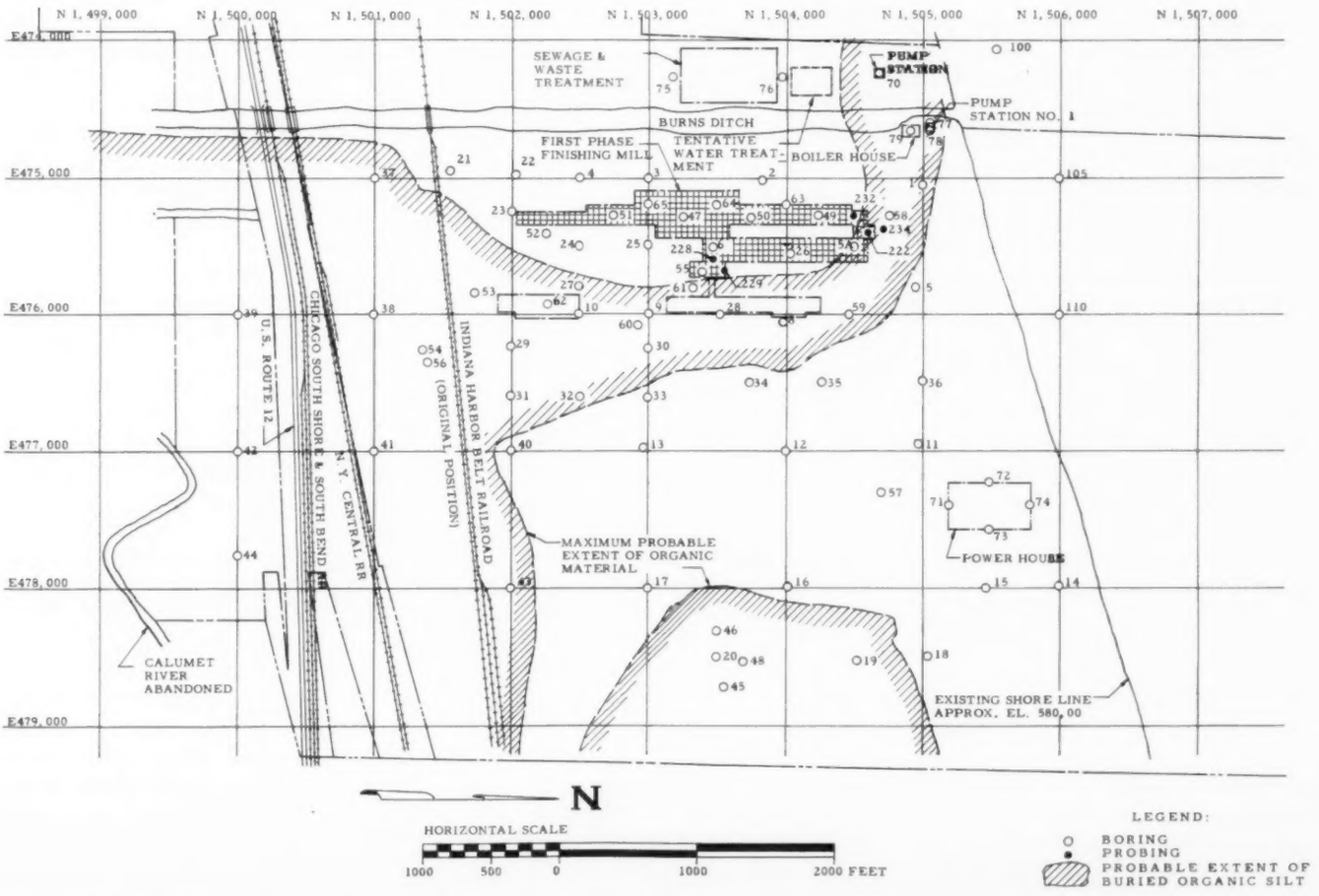
Till sheets, lake sediments mostly silts and clays and beach sands, occur below elevation 540. The plastic soils of silt and clay between elevation 540 and 500 have consistencies which are medium stiff to stiff, the firmer soils being found beneath the dune strip. Below elevation 500 to bedrock the plastic soils are very stiff to stiff. The condition of the soil below elevation 500 clearly attests to preloading by glacial ice that advanced and retreated across the site during the early stages of Lake Chicago.

The approximate areal extent of the organic material beneath the first phase finishing mill is outlined in Figure 2. The shading does not imply that the organic deposits are of constant thickness or continuous over the whole of the shaded area. Rather the organic deposits are found in pockets of varying shape and size, on the whole similar to those in existing low-lying depressions suited for the growth of swampy vegetation.

The erratic nature of the silt and clay deposits as shown in Figure 3 bespeak of an intricate series of lakes that formed as glacial ice melted, and low-lying land that was inundated and exposed as the lake level rose and fell.

In the following section it is shown that the silts and clays deposited during the advance and retreat of the glaciers have been compressed beneath the weight

Figure 2 — Exploratory borings were made to determine the limits of the preloaded area.



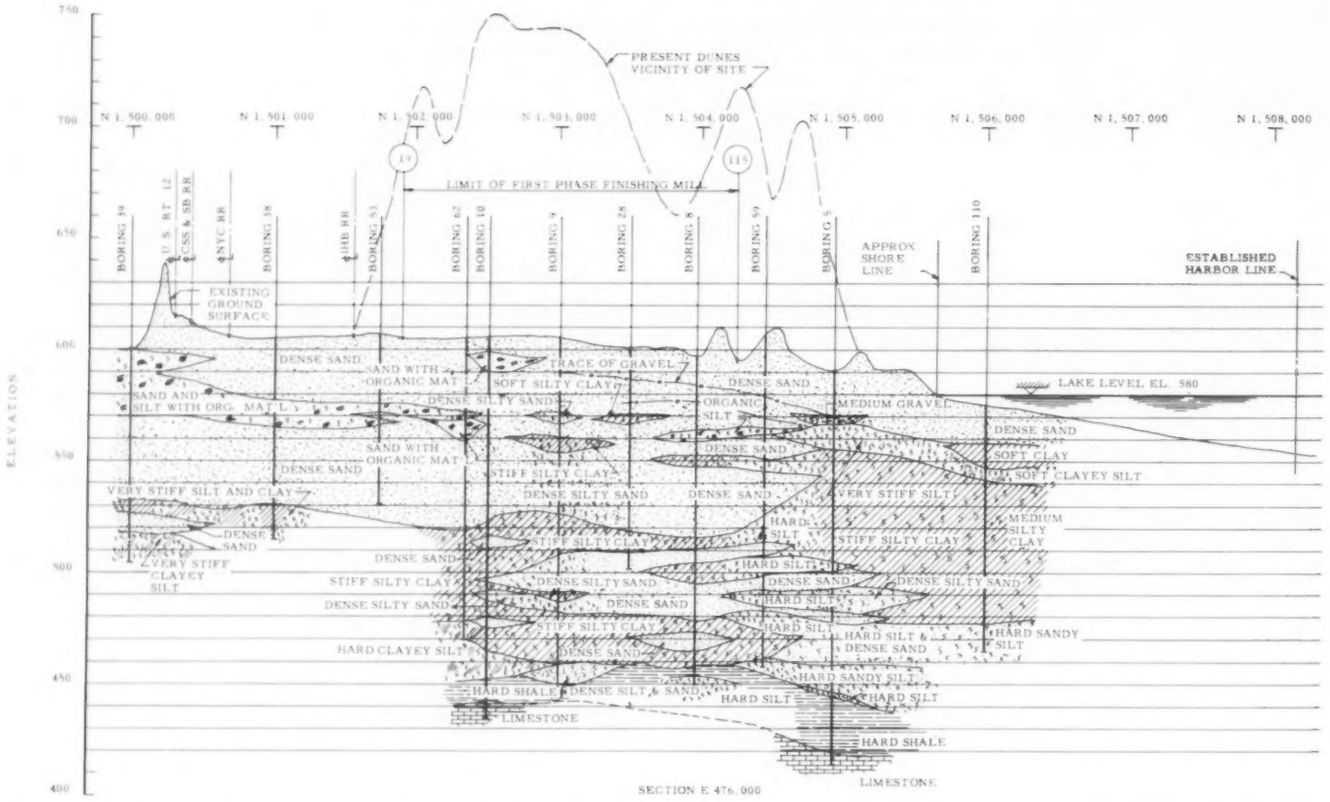


Figure 3 — The various deposit compositions and their random placement indicated that the area was once covered with numerous lakes.

of ice and vanished lake sediments which were eroded during low water stages of the lake. The organic materials above elevation 540 have been preloaded only within the narrow strip of land paralleling the shoreline and occupied by the dunes. South of the Indiana Harbor Belt Railroad the soils have not been subjected to preloading by dunes.

North of the present shoreline recent lake sediments such as the soft clay found in boring 10 between elevations 545 and 560 and buried under about 20 ft of sand have not been preloaded. Such deposits are termed normally loaded and have been consolidated only under the weight of their soil overburden.

In general three distinct and different soil deposits underlie the site. These, in order of oldest deposition above the shale and limestone bedrock are:

Glacial deposits—These comprise till sheets, lake sediments mostly silts and clays showing some semblance of stratification and beach sands, all formed during the recent geologic past when glaciers overran the region. These deposits were found below elevation 540. The first of the glaciers[2] reshaped the Great Lakes basin and removed surface soils. As the glaciers moved southward from the Great Lakes basin, the melt waters formed large lakes between the ice front and the higher lands to the south. As the last of the Wisconsin glaciers advanced across the lake covering the site, soil and rock debris carried by the glacier were deposited on the bottom of early Lake Chicago as till sheets. As the glacier advanced, this till sheet was compressed under the massive weight of the ice. Still later when the ice temporarily retreated, an additional till sheet was laid down. These soils were again compressed during the next ice advance. At the plant site there are three such till sheets. These glacial deposits preloaded by ice have high strength and bearing properties.

Lake sediments—Silts and clays which are probably accumulations of the first and second Glenwood stages of Lake Chicago[3] lie between elevations 565 and 540. The soils are firm and have good strength and bearing properties. Their preloading occurred mostly under the weight of vanished lake sediments and sand dunes. A study of soil data, in particular water content, indicates that similar soils at the same depth have higher strengths when found beneath the dune strip.

Organic deposits, beach sands and dunes—Deposition of these soils probably occurred during the Two Creeks low-water stage and the following high water of the Glenwood III and Calumet stages of Lake Chicago. Geologic data place the lake level during the low-water stage at elevations below 580. It would appear from the position and soil properties of the organic deposits found at the site that the low-water level of the Two Creeks stage was at about elevation 565. The organic deposits formed just south of the beach in the depressed regions some 12,000 years ago following the last retreat of the glaciers from the Great Lakes basin. The organic deposits were in turn covered by a thick mantle of sand to approximately elevation 600. The two distinct gravelly surfaces denoted by dashed lines on the soil profile, Figure 3, and in particular the lens of gravel found at elevation 565 in boring 5 suggest that these beach deposits were formed during the Glenwood III stage while the lake level was rising from elevation 565 to 640.

The high dunes found east and west of the site covering a narrow strip of land one mile deep and paralleling

the shoreline were probably formed during the Toleston stage when Lake Chicago had receded to elevation 605. The Toleston stage followed the Calumet high water stage of elevation 640 and occurred some 9000 years ago.

Considering that the water level of Lake Chicago did not rise above elevation 605 following the Toleston stage there is no reason to suspect that the buried organic deposits beyond the limits of the dunes have been preloaded. Indeed, borings located north and south of the dune strip revealed organic deposits and lake sediments that are soft and compressible.

However, where dunes have been removed the strength of the buried organic deposits is consistent with the amount of preloading by the vanished dunes. Where topographic maps are available the preload pressure imposed on an area can be determined and the bearing capacity of the soils established.

East and west of the site the dunes rise from depressions at elevation 600 to heights at 700 and 800. The dunes have been altered and modified little by wind. There is soil data to suggest that the migration of the dunes was hindered by vegetation and that little or no shifting occurred. Hence, it is reasonable to assume that organic deposits buried beneath the sand in existing areas of low depressions have not been preloaded. Such compressible materials should be found at varying depths between the low-water level of the Two Creeks stage at elevation 565 and that of the Toleston stage at 605. This is the case.

South of the Indiana Harbor Belt Railroad the ground surface has a gentle relief as it is practically the unaltered lake bottom of the predecessors of the present Lake Michigan. The relatively low-lying flat lands drained by Burns Ditch have not been preloaded by sand dunes. The buried organic deposits south of the Indiana Harbor Belt are soft and compressible. Also, north of the present shoreline recent lake sediments such as the soft clays buried under approximately 20 ft of sand have not been preloaded.

Second phase of exploration—As the layout of the first phase finishing mill took shape and various facilities such as the pump station, power house and sewage treatment plant were located, borings were located and drilled in areas where heavy column loads, intricate machinery and heavy storage would occur. In order to establish the strength of the soils, particular attention was given to securing undisturbed soil samples for laboratory testing. The borings were concentrated in the area of the proposed first phase finishing mill and were designed to check the uniformity of the soil strata and to provide conclusive data as to the magnitude and areal extent of preloading. Finally, these borings were planned to establish the extent and the characteristics of organic deposits which might underlie the mill foundations. A log of a typical boring giving the penetration resistance and water content is shown in Figure 4. The log gives a detailed description of the soils, their penetration resistance* and water content** found along the section shown in Figure 3.

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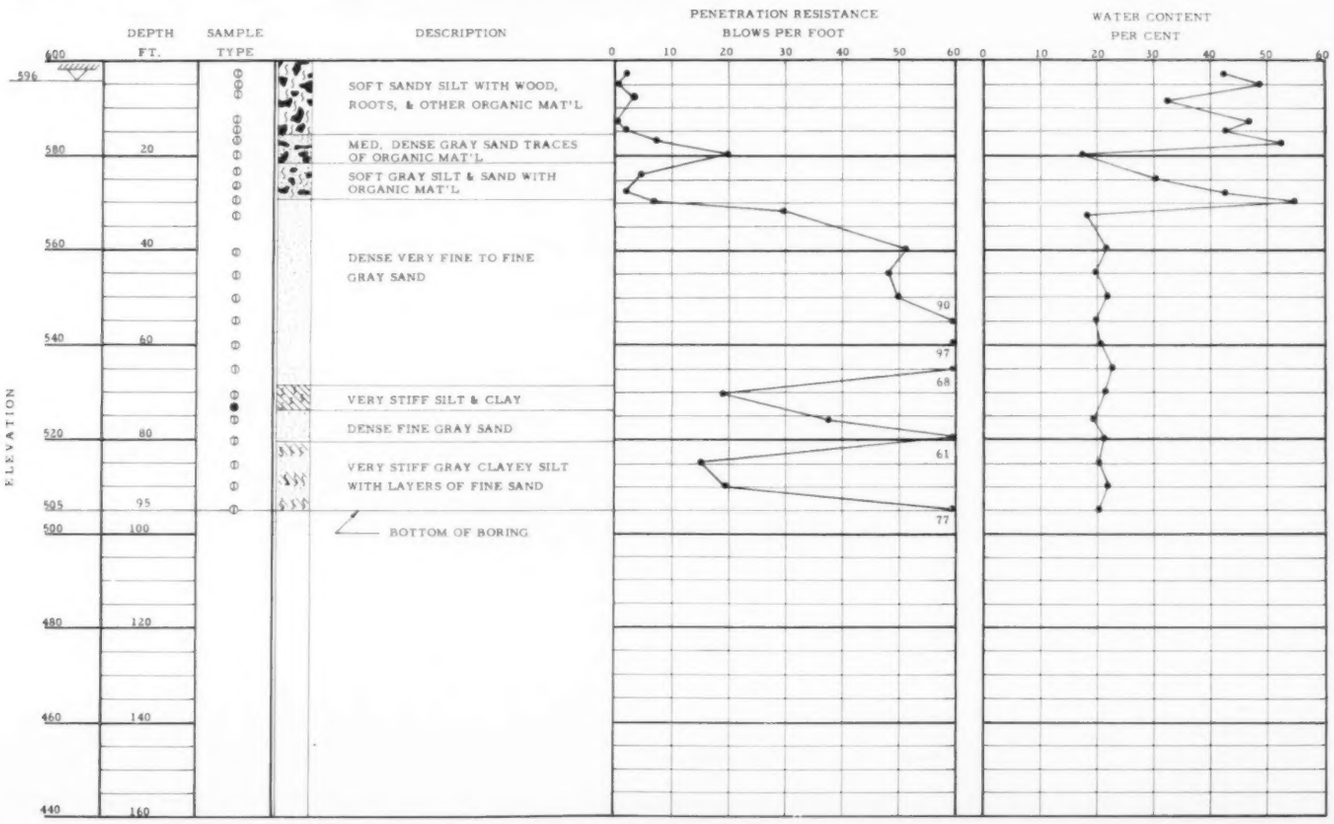
* Standard penetration test conducted during drilling and spoon sampling is the number of blows required to drive a 2-in. OD split-spoon sampler one ft with a 140-lb hammer falling freely through a height of 30 in.

** Water content given as a percentage is the ratio of the weight of water to dry weight of soil.

Figure 4 — Log boring 39 indicates the varying penetration resistance and the many soils found in one boring. Shown also are typical penetration resistance and water content data.



CORRELATION AND INTERPRETATION DATA

The clay and silt layers were formed during the advance and retreat of glaciers over the site. By careful soil boring and equally careful testing the major ice movements could be established. Since much of the soil was deposited as sediment, it originally had a high water content, ranging from 30 to 40 per cent. However, as additional layer accumulated above the original sediment, the latter was consolidated and the water squeezed out of it. This coupled with the added weight of glacial ice further reduced its water content to about 20 per cent and in the lower till sheets to 15 per cent. Therefore, the different preloadings of the manifold sediments were established by observing distinct changes in water content profiles. These suggest that the mill site between the present shoreline and the Indiana Harbor Belt Railroad was loaded by dunes over and above any preload by eroded lake sediment and ice. One can conclude then, that any

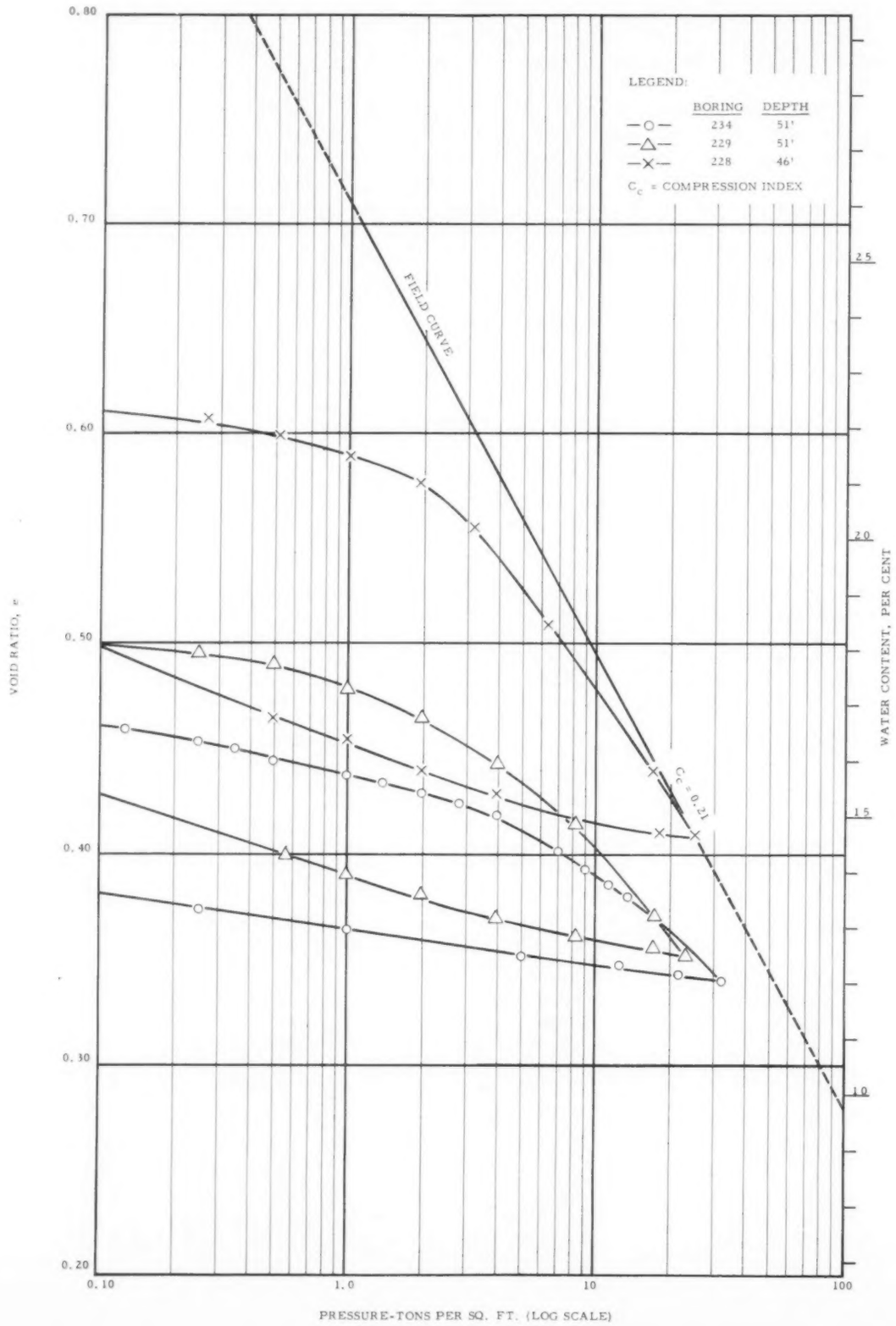


Figure 5 — The void ratio-water content curve indicates a correlation between consolidation and water content for clayey silts.

organic deposit above elevation 540 and buried beneath the dune strip is also preloaded. There remains the question, how much?

It will be shown later that fine-grain deposits of silty clay and clayey silt possessing water contents less than 20 per cent, have excellent bearing strength and can sustain the load of a mill with negligible settlement. The point to be emphasized is that careful observations of water content on similar soils are an excellent means of establishing differences in preloading and its areal extent.

Differences in water content as described above for the silt and clay layers are even more pronounced in the buried organic silts that were found above elevation 560 beneath and south of the dune strip. For example, the organic material in boring 8 at elevation 562 had a water content of 38 per cent. In boring 39 at elevation 570 as shown in Figure 4, the water content was 55 per cent. A lower water content in the same organic material as observed at boring 8 can only be attributed to preloading by sand dunes.

It is interesting to note for the same silt and clay layers below elevation 540 that the average water content of the soil beneath the dune strip is slightly less than those north and south of the strip.

The void ratio-pressure curve for soils has the same significance as the stress-strain curve for metals. Void ratio is given by the quotient, volume of voids to volume of solid soil substance. The compression index and the preconsolidation pressure of soils are comparable to the modulus of elasticity and yield strength for metals. The deformation of soils and consequently settlement stems from changes in the volume of the voids per unit volume of soil. Volumetric strains, which are integrated over the depth of a soil layer to give settlement, are determined from changes in void ratio.

In saturated soils the void spaces are completely filled with water and hence any change in water content will denote a change in void ratio. A lower water content indicates the soil has been compressed and possesses a higher bearing capacity and greater ability to support loads without serious settlement. Changes in volume associated with the deformation of the actual solid soil substance is neglected. The order of magnitude of these deformations is many times smaller than that associated with changes in void spaces.

In this foundation investigation soil testing was directed to establish accurate profiles of water content with changes in depth of soil. Consolidation tests were conducted on a limited number of selected samples of different soil types. A typical correlation between consolidation data and water content for clayey silts is shown in Figure 5. Void ratio is plotted as ordinate on the left side of the figure and water content on the right. The curve if rotated 90 degrees counter clockwise is similar in shape to the stress-strain curve for a strain-hardening metal. Soils in a sense behave like rigid strain-hardening materials. The changes in volume during recompression and rebound are negligible compared to the changes in volume that occur in the strain-hardening range. Large distortions occur only after the preconsolidation (yield strength) of the soils is exceeded. Hence, in design it is first necessary to determine the initial void ratio and existing overburden pressure of the soil. The existing state of stress can be readily computed once the depth of the soil sample beneath the ground surface is known. The initial void ratio requires a determination of the dry unit weight of the soil sample and the specific gravity of the solid soil substance. Carefully secured undisturbed soil samples are needed for unit weight tests. On the other hand measurements of water content can be made from disturbed samples obtained during normal drilling operations.

The silt and clay deposits have been subjected to several cycles of loading and unloading by ice, eroded sediments and sand dunes. For consolidation testing different undisturbed samples of soils which had been normally loaded or subjected to one or more cycles of loading and unloading were selected. Figure 5 gives the laboratory recompression and rebound curves for clayey silt samples. The existing overburden pressure for each sample is 1.5 tons per sq ft. Before large volume changes can occur, a pressure equal in amount to the difference between the preconsolidation and existing overburden pressures has to be applied to the soil. For example, the clayey silt taken from boring 229 at a depth of 51 ft below the surface has been preconsolidated under a pressure of about 10 tons per sq ft. Before large settlements can occur a pressure of 8.5 tons per sq ft would have to be applied by the foundation. Undoubtedly the soil has been preloaded by high sand dunes since preconsolidation pressures of this amount would require loading by dunes some 200 ft in height.

Hence, it is important to correlate water content with the consolidation characteristics of a soil. For saturated soils below the ground water level, water content profiles readily determined from spoon samples obtained during drilling operations prove invaluable in assessing the strength and compressibility of a soil.

Water contents for plastic soils such as silts and clays are more meaningful in a foundation study than the resistance to penetration of a spoon sampler as measured by the standard penetration test in drilling operations.

It is assumed in this discussion that the ground surface is at elevation 600 and that the soils beneath the site have been preloaded in varying amounts by dunes and glacial ice. The amount of the preloading is not known but it can be estimated from the void ratio-pressure field curve when the water content is known. By considering the clayey silts in the interval between elevations 580 and 560, having an average overburden pressure of 1.0 ton per sq ft, all soils with void ratios greater than 0.70 or water contents greater than 25 per cent would be considered normally loaded. Arbitrarily low sand dunes have been selected as extending from elevation 600 to 650. The pressure line for dunes 50-ft high (2.5 tons per sq ft) intersects the field curve on Figure 5 at a void ratio of 0.60. Hence, water contents in the range between 22 and 25 per cent imply that the clayey silts have been preloaded by low sand dunes that attained a maximum height of 50 ft above the rough mill grade. Similarly, medium sand dunes are those ranging from elevation 650 to 700. The intersections of the respective pressure lines with the field curve are at void ratios of 0.60 and 0.55 and correspondingly clayey silts having water contents in the interval between 20 and 22 per cent would be loaded by medium sand dunes. Clayey silts loaded by high sand

dunes (elevations 700 to 800) would have void ratios between 0.55 and 0.49 and water contents between 18 and 20 per cent. For pressures greater than 10 tons per sq ft, the void ratios are less than 0.50 and water contents are less than 18 per cent. This heavy compression of the soil could have been produced only by dunes in excess of 200 ft in height or by glacial ice. There are no records to suggest that higher dunes have covered the area and hence preloading must have been under the weight of ice.

Sharp variations in water content are only evident in the organic materials above elevation 560 where the material lies either beneath the dune strip or outside the dune strip and in the soft clay sediments in the lake bottom. From these data it is certain that, in general, the soils below elevation 560 have been compressed by ice and are in a firm state and that the buried organic deposits above 560 have been preloaded in varying amounts only when found under the area that was occupied by the mined dunes.

Over the dune area, spread footings and mat foundations were designed for a safe allowable soil pressure of 4500 lb per sq ft. On the site there were regions of low-lying depressions among the high dunes. One existed in the vicinity of boring 20, where little preloading of organic deposits was found. Therefore, there is a need to clearly delineate and establish the extent of the low-lying areas. Hence, a boring program in any future work should be laid out to establish the areal extent of the organic deposits that have not been sufficiently preloaded to allow for economical spread footing design.

North and south of the dune strip where soils have not been preloaded and where organic materials or soft clays lie buried deep beneath the surface sand, serious settlement will occur unless proper steps are taken to either by-pass the soft deposits with piles or caisson foundations or to preload the area artificially prior to construction of the foundations.

Third phase of explorations—Consolidation tests on samples with organic material reflected the same preload as had been observed in the clayey silts. It was decided at this juncture to probe under each building in several places to define the limits of the organic deposits and to check their uniformity with respect to strength and preloading characteristics. For instance if there had been an area where the original dunes were low there might have been buried organic deposits either not preloaded at all or insufficiently preloaded to safely carry the 4500 lb per sq ft bearing pressure that was recommended. The probing that was done constituted the third phase of exploration and was designed almost exclusively to define the areal extent, depth and characteristics of the organic deposits.

The probes were standard soil borings carried to various depths depending upon the size and depth of the foundation that was to be built over the area. This phase of the work was carried on during construction.

The tin temper mill was the first area where extensive organic deposits were found and is typical of the situation that was repeated several times before the mill was completed.

The first boring that penetrated the organic deposits showed standard penetration resistances of two to three blows per ft. This indicated a much softer and weaker deposit than had been anticipated. Several more borings resulted in similar data. A close check of field operations disclosed a slight deviation from the drilling procedure that had gone undetected. Borings had been advanced using driller's mud (bentonite) to wash out the cuttings. The probings were drilled, however, using clear water. The effect of clear water on the silt was to soften it and thus yield very low, unrealistic values of penetration resistance. The viscosity of the bentonite solution was such as to prevent it from penetrating the silt. However, even with the use of bentonite, the penetration resistance showed a weaker material than subsequent laboratory tests which were conducted on undisturbed samples of these soils. This indicates that penetration resistance data for the organic deposits is uneconomically conservative. Several undisturbed samples were obtained and subjected to tests. The unconfined compressive strength of the material never dropped below one ton per sq ft and in most cases was about 1.5 to 2 tons per sq ft. This high strength is attributed to the low water content of the material, the large amount of silt present and the fibrous structure of the organic material. The water contents were about 30 to 40 per cent. In one case it reached 60 per cent. The consolidation data were equally conclusive. Preconsolidation pressures of four tons per sq ft were obtained consistently. With existing overburden pressures of one ton per sq ft on the organic soils, the safe design pressure for the tin temper mill was set at 4500 lb per sq ft. To reduce the hazard of small differential settlements from variations in load distribution resulting from shifting coils in storage, the tin temper mill rests on a mat foundation. The coil storage area was cut free from the rest of the mill.

This same approach was used through the third phase of exploration beneath the 5-stand cold reduction mill, pickling line, tinning line and other mill units underlain by organic deposits. No reductions in bearing were necessary.

Sand—Having established the nature and strength of the till sheets and organic deposits, it remained to assess the suitability of the sand for foundation support.

Tests in the sand in its natural state and in the laboratory showed that it was in a medium dense to dense state. Since it had been deposited along the shoreline of a lake and had been loaded by the dunes that were subsequently mined it was not surpising to find it in such a dense state. Tests have shown that sands in such a dense state (a relative density greater than 70 per cent) have adequate strength to support foundations subjected to both static and vibratory loads. A design bearing pressure of 4500 lb per sq ft was adopted for all foundations within the area of the mined dunes.

Since floors and foundations will all rest in sand, proper compaction and control of filling and backfilling operations was important. Filling along the lake shore presented an opportunity to evaluate the effectiveness of various methods of compaction. During construction the sand in the cut area was saturated as well as in the fill area. Water was pumped directly from the lake through a header line and allowed to spray out through small plugs removed from the pipe. Actual compactive effort was no more than the weight and vibration of earth-moving equipment passing over the area. Field

density tests showed that this method was both effective and economical requiring a minimum of compactive effort and equipment.

This procedure was used for all backfilling except that a crawler tractor was used to supply compaction. This piece of equipment was used for several reasons; it was sufficiently maneuverable to operate within building lines, it could operate near the footings and walls and although the psi loading is small as a result of the wide track, it provides excellent vibration which is needed in the compaction of granular materials.

In-place density tests beneath the footings themselves were also made. These were generally in undisturbed sand. The data provided a check on sand at all depths down to 30 ft below mill grade. The data substantiated the density and strength of the sand as determined from undisturbed soil samples.

FOUNDATIONS

A correlation and interpretation of the subsurface explorations and laboratory tests with the geologic history of the site proved that the use of spread footings to support column loads and mat foundations to support machinery units directly on the sand was both sound and economical. The foundations were designed for an average soil pressure of 4500 lb per sq ft and a maximum toe pressure of 6000 lb per sq ft.

The 3-phase subsurface explorations program completely established the areas that had been preloaded. The first phase finishing mill covers an area which was loaded beneath dunes at least 50-ft high. Considering the variations in water content and the consolidation data for the organic silts there is ample evidence that the dunes had attained heights of 150 ft above the mill grade. There is no question about the strength of the underlying silt and clay deposits which were preloaded by glacial ice.

Even though the resistances to penetration of the silt deposits between surface elevation 600 and elevation 560 suggested apparent soft material, a study of strength data and water contents clearly showed that the standard penetration test was not indicative of the strength of the materials and should not be used in determining the type of foundation to be selected. If the standard penetration test data had been used, it would have been necessary to drive piles to by-pass the organic deposits. The piles would have had to penetrate, on the average, to approximately elevation 550, some 30 ft below the base of the foundations.

As mentioned earlier, the savings in eliminating pile and caisson foundations amounted to very appreciable savings since full advantage was taken of preloading of the site by sand dunes and of the fact that safe foundation pressures of 4500 lb per sq ft could be imposed without significant settlement.

Ground water varied throughout the site between the mean level of Lake Michigan at elevation 580 to about 590. With the removal of the dunes the ground water level receded and appeared to be stabilized at approximately the level of the lake. No difficulties were encountered in maintaining open excavations during construction where the base of the footings lay below ground water level. The use of well points was required with deep excavations but shallow excavations were readily maintained dry by pumping from sumps.

Figure 6 — Settlement in the preloaded area was negligible as the mill was constructed.

SETTLEMENT

Settlement observations were taken at various stages of construction of the foundations. In the area preloaded by dunes and which supports all of the first phase finishing mill, settlement was negligible about one year after construction, for buildings which were under cover as shown in Figure 6 and machinery units as shown in Figure 7.

The opportunity presented itself to conduct a large scale consolidation test on the site. The boiler house was to be constructed over seven ft of silty clay. This area was near the lake shore and it was not surprising to find that it had not been preloaded.

The boiler house will rest on 20 ft of fill which was required to bring the area to yard grade. The boiler house itself represented only a small percentage of the total loading on the silty clay strata. The load that would cause settlement was the fill itself about 22 ft deep producing a surcharge of 1.1 ton per sq ft. Settlement calculations showed that to achieve 90 per cent

Figure 7 — A mat foundation was used for the 5-stand cold reduction mill.

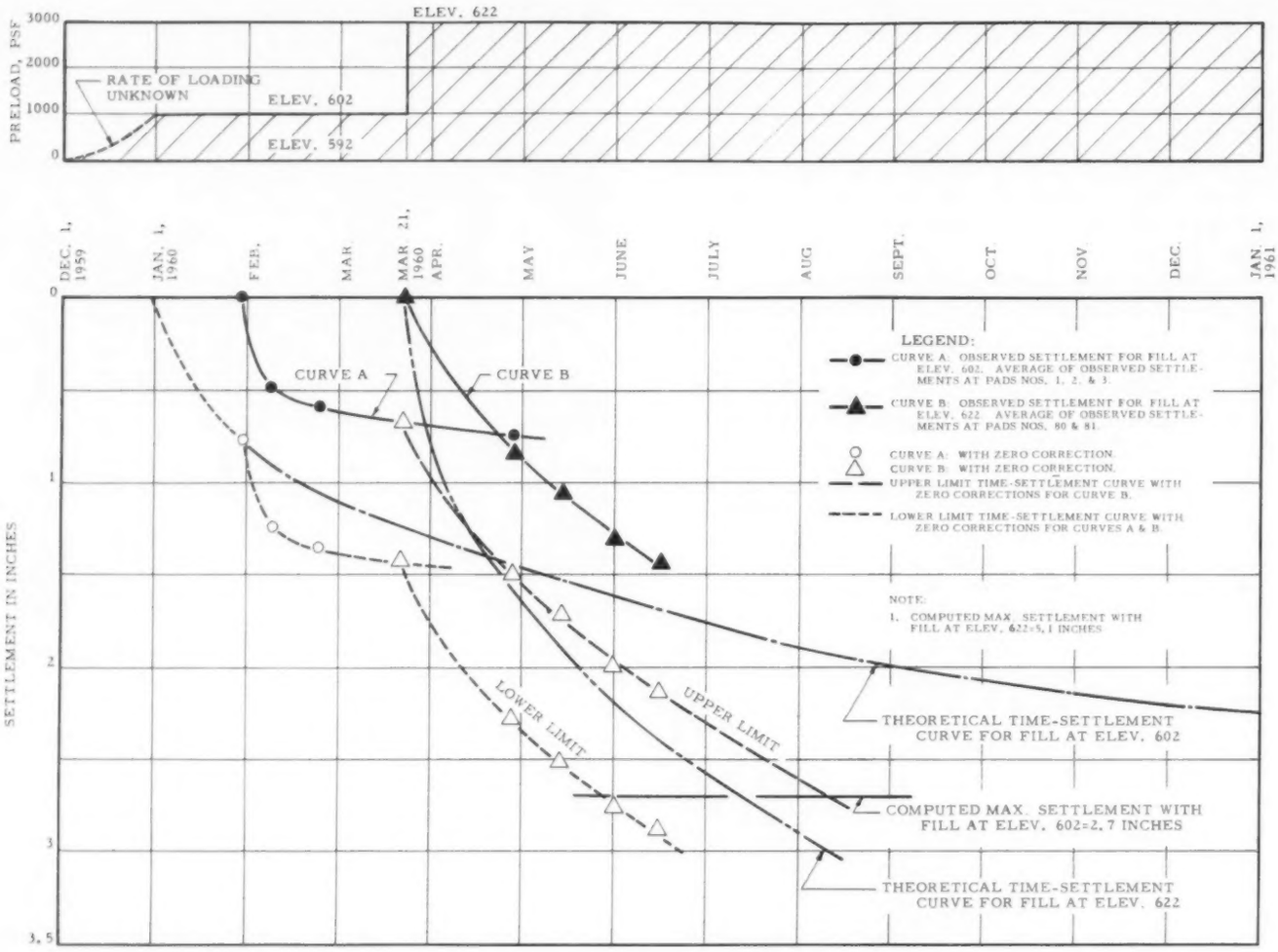


Figure 8 — Artificial preloading was used in the area where the boiler house was to be constructed, and data was obtained to be used for future construction design.

of the total settlement would take about two years. Construction, however, was to begin within six months. Knowing the time-settlement relationship for the soil, it was recommended that the area be raised to elevation 622 which represented essentially a 20-ft sand dune. Based on tests, this load was to achieve 90 per cent consolidation within six months. Settlement observation points were installed in the area. The load was applied in two phases. The area was filled with sand to grade about 20 ft and then raised another 20 ft which was to be removed when consolidation was complete. In essence where nature neglected to preload the area it was done artificially. Figure 8 shows a computed theoretical curve of time-settlement and the actual observed data. The site was ready for construction within the allotted six months.

The data obtained from this operation were valuable in providing a verification of laboratory tests and in furnishing design criteria for future construction.

SUMMARY

The comprehensive exploration program carried out on the mill site yielded data that resulted in simple, economical construction of foundations. Specifically, the program made it possible to take advantage of the natural preloading of the site by sand dunes, lake sediments and glacial ice. To have assumed in the interests of safety that the site had not been preloaded would have led to excessive cost of foundations in the use of piles or caissons to by-pass the upper layers of buried organic soils and lake sediments. The use of spread footings and mat foundations and the large savings realized were made possible only by detailed subsurface explorations conducted in phases which preceded and paralleled the design and construction of the foundations. Particular attention was given to determination of accurate and complete water content profiles and the correlation of these water contents with consolidation test data. Standard penetration test data were used only as a guide, not as design criteria.

Close cooperation between the engineers of Midwest Steel Corp. and the consultant saved time and money as work progressed. By keeping a close check on construction and observing significant items the consultant was to supply corrective measures during construction whenever such measures were needed.

During the entire program, an eye was kept to the future. As expansion is the norm in the steel industry, all the data and experience gained are ready to be put to use again where the need is apparent.

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Discussion

PRESENTED BY

R. A. KRAUS, Construction Manager, Republic Steel Corp., Warren, Ohio

ELIO D'APPOLONIA, President, E. D'Appolonia Associates, Pittsburgh, Pa.

C. F. LARSON, Chief Construction Engineer, Mesta Machine Co., Pittsburgh, Pa.

KENNETH G. HUNT, Division Superintendent, Maintenance and Construction, Crucible Steel Co. of America, Midland, Pa.

L. A. FUGASSI, Chief Engineer, Midwest Steel Corp., Div. of National Steel Corp., Valparaiso, Ind.

L. S. MOBLEY, Chief Engineer, Gulf Steel Div., Republic Steel Corp., Gadsden, Ala.

R. A. Kraus: Those of us that are familiar with construction on the average steel mill site are more familiar with reclaimed farm land or possibly with a swamp filled in with ashes, flue dust, coke plant and open hearth debris rather than compacted sand as found in the site described in this paper.

From some of your figures you indicated that you would require approximately 30-ft-long piles, and based on our experience 30-ft piles would perhaps represent three cu yd of concrete in place.

In other words, you can afford to place an additional three cu yd of concrete for each pile eliminated. Inasmuch as spread footers for building columns and equipment and other changes in design obviously increased your concrete requirement substantially, and that the exploration costs were considerably higher than if piling would have been used, it would be appreciated if you might comment on the net savings by not using piling.

Elio D'Appolonia: Piles were not necessary at the site. The sand and underlying clay deposits had adequate strength to support mill loads on spread footings and mat foundations. Such foundations are in most cases more economical than the use of pile foundations. It is true that a subsurface exploration and laboratory testing program required for the spread footing design is more costly than one required for pile foundations. Taking into consideration the cost of the subsurface investigation and comparing the spread footing and pile foundation designs it was shown, in this case, that an actual saving was obtained with the use of spread footings. The arrangement of combined footings in many cases dictated the size of the footing. This would have been true regardless whether a spread footing or pile foundation was used. The only economy that could be achieved with a pile foundation would be a reduction in size of the pile cap which combined with the cost of driving piles would have to be less than that of a spread footing. At this site the allowable pressure was 4500 lb per sq ft with maximum allowable pressures for combined loading of 6000 lb per sq ft. The spread footing and mat foundations gave greater economy than pile foundations.

It is extremely difficult to generalize on the economy of one type of foundation over the other. The relative economy must be worked out on a site to site basis, taking into account loads, arrangement of footings, strength of soil strata, construction costs and other factors. The end result is always to use the most economical foundation consistent with a predetermined factor of safety.

C. F. Larson: Foundation engineers soon realize that soils differ in most important aspects from other materials which they have to handle. The strength and deformation characteristics are not constant and their behavior under stress is strongly affected by density and relative proportions of water and air that fills the voids.

The analysis of stress distribution in soil masses is a complex problem of a highly indeterminable nature and therefore looked upon by many with skepticism. It is however the responsibility of the foundation engineer to sufficiently familiarize himself with this subject so as to determine the need for advice and in conjunction with the consultants arrive at an economical and practical solution.

To the foundation engineer soil bearing values are of course the very fundamental basis on which designs are established since the function of a foundation is to support the loads resting on it and properly distributing the loads satisfactorily over the surfaces of the soil layers on which it rests. Aside from the well prepared technical data contained in this paper as proof of preloading it is of interest to note the large scope of the survey.

To what extent can the contour of Lake Chicago or Toleston beach of 9000 years ago be geographically plotted?

While it is economically feasible to design heavy mill foundations for soil bearing values of 4500 lb per sq ft one should not be misled to use this factor as a criteria. Certainly plant sites being fortunate in having sand and gravel sub-base where permissible soil bearing values of 8000 lb per sq ft are used can expect even more economical foundation conditions, particularly in view of the exceedingly large live load factors now considered.

Out of this arises an idea which could possibly lead to a project for the AISE. This would be to undertake the pooling of all soils reports now in possession of the steel industry. This could be an inmeasurable value in connection with proposed expansion and improvement programs.

Elio D'Appolonia: The Toleston beach sands and the underlying deposits that have been heavily preloaded were defined by sharp changes in water content. Where the water content was of the order of the plastic limit or less, it clearly implied that such deposits had been preconsolidated by vanished strata of one form or another. Furthermore, the two layers of sand and gravel that had a gentle slope between elevations 565 and 580 to 600 appeared to be remnants associated with rising and falling lake level. These geological facts correlated with much of the study that has been made of the

Michigan basin are quite consistent with the findings in the Chicago area and with published data on the location and the position of the Toleston beach and earlier deposits. These data permitted a correlation and description of the soil strata at the site.

Research at the University of Chicago, using carbon 14 dating and time scales determined by geologists by studying varved sediments established the period of deposition of sands and clays at the site.

With reference to allowable bearing pressures the recommended bearing pressure of 4500 lb per sq ft and a maximum allowable pressure for combined loading of 6000 lb per sq ft is that consistent with our interpretation of the soil data. It is true that the underlying soil strata have been preloaded to pressures many times greater than the maximum soil pressures used in design. However, besides density of sand and preloading, there were other factors, such as buried swamp deposits, superimposed soil pressures, settlement limitations and so forth, that had to be considered in selecting the design for allowable soil pressure. Considering these the above maximum pressures were adopted for design.

The last comment by Mr. Larson is indeed worthy of careful consideration. I think it is the type of study that many engineers with steel companies have started but few have followed through. The reason being that steel mill engineers and personnel are so occupied with the many and varied everyday problems in operation and expansion that too often the review and correlation of accumulated data are neglected. The steel industry is remiss in not using its past history and the wealth of information on foundations that is often contained in its files. Too often a subsurface exploration program is started without reviewing in detail the history and the performance of foundations already in use.

Certainly any effort by the AISE to correlate data on a regional basis would eventually bring a saving to the steel industry in foundation design and construction. Such correlations should be used as a guide in planning foundation investigations. Information properly analyzed on a regional basis is often sufficient for preliminary design and cost estimates. Once a layout has been completed a sufficient and adequate program of subsurface investigation should be planned to assure that the soils have adequate strength to support the foundation loads within the predetermined limits of settlement. Taking advantage of data on the performance of previously constructed foundations the cost of such a foundation investigation can be minimized.

In foundation engineering, case histories are essential in achieving maximum economy and safety in foundation design and construction.

Kenneth G. Hunt: Did you use any high early cement?

L. A. Fugassi: In certain applications, yes.

Kenneth G. Hunt: Did you use any slag cement? If you had piled the area would you have used a lesser quantity of cement?

Did you use any reinforcing rod or mat reinforcing such as highway mesh? Also, did you use any pozzolith cement?

Did you do any cementing of the soil in any place? By that I mean injection of cement by the use of well points.

Of course, from your comments I would assume that these things were absolutely unnecessary, but these things would be very interesting to find out.

L. A. Fugassi: An excessive amount of reinforcing rod was not used in the design. It was a straight mat pad, double rodded top and bottom, which is standard in this type of foundation. Slag concrete was used.

Additives were used, but not as a general rule. Additives were used in places where it was felt that a high early setting was required because of construction schedules, there are several high early additives of the same function under different trade names.

L. S. Mobley: This survey was made on virgin territory. In places where sandy soil would exist inside a plant, what has been your experience on vibrating? Would this have any particular application on the job to which you referred?

Elio D'Appolonia: With reference to vibration from plant equipment, there was no need to densify the sand at this site since it was already in a dense state. It was felt that vibration from trains, mill equipment and such would not have sufficient energy to cause further densification of the sand.

Where vibrations have led to settlement of foundations on a sandy soil implies that the sand has been reoriented into a more dense state and that any additional settlement will probably be less than that which has already occurred. It has been my experience that where vibrations have produced settlement of granular soils that the settlement occurred rapidly and then ceased beneath the particular vibrating unit. Additional settlement was unimportant in comparison to the initial settlement that occurred.

With reference to subsurface exploration within a mill, you are well aware of the difficulties because of headroom, clearances, operations and so forth. Where such an investigation is required, a careful review and study of the problem itself is recommended taking into account the arrangement, size of footings, loads and so forth. If vibrations are serious and continued settlement is occurring, seismograph surveys should be made to determine the frequency and amplitude of vibrations. Such surveys are often useful in suggesting remedial measures for isolating the predominant contributor to the ambient vibrations. To evaluate the strength properties of the soil strata at least one complete plot of density with depth should be obtained. Attention should be given to the securing of undisturbed soil samples to determine the thickness of each soil strata and the accurate unit weight of the sand in-situ.

The use of standard penetration tests to determine the strength of the underlying sand can be misleading and are of little or no value where settlement is occurring with transmission of vibrations through the sand deposits. Standard penetration tests may be used for correlation but careful testing and securing of undisturbed soil samples would well justify the cost involved in obtaining such samples. The reliability of the data and its interpretation is necessary for the selection of proper remedial measures. In-situ densities can then be compared to the minimum and maximum densities determined in the laboratory and a decision made as to the amount and possible continuance of settlement and what remedial measures, if any, may be necessary to avoid further settlement. ▲

GREASE ON TAP

by C. A. BAILEY, Lubrication Engineer, National Tube Div., United States Steel Corp.,
and D. R. McCAA, Product Manager, Standard Products, American Bridge Div., United States Steel Corp., Pittsburgh, Pa.

BULK grease handling is now a reality in many mills, but it must be remembered that bulk handling is only a means of delivering grease to a plant. The plant still must dispense the grease from bulk containers to lubrication points throughout the plant. From a plant's view, the most practical way of doing this would be to make grease a mill utility-item. If grease were placed in this category, then every plant could have grease on tap and yet realize direct benefits. Lubrication costs could be cut through reductions in handling costs, warm-up time and chances of contamination, while eliminating the ever-present and costly problem of residuary grease. Indirect benefits would also be realized through improved safety and housekeeping, while at the same time, the plant could conserve on valuable floor space. Therefore, it can rightly be said that overall operating costs would be reduced through the combined benefits accrued by the installation of bulk grease facilities and the addition of grease on tap.

The idea of making grease a mill utility-item has not just grown; rather, it has evolved as the next natural stage growing out of developments in three areas: lubricants, application methods and containers. These three areas are separate, yet their developments have been interrelated. A development in one area did not occur without previous improvements in the other areas. In this manner a chain of improvements was established. In order to better understand our present position, let us go back and trace these developments to the present day.

LUBRICANTS AND APPLICATION METHODS

Early in the 1920's black oil was widely used throughout the steel industry; for example, in 1924 the monthly consumption of one of the principal steel producing plants was 75,000 gal. The oil arrived at the plant in tank cars and was stored at a central station; it was trucked from central storage to the consuming departments where, generally, it was applied to the machinery by hand. Other lubricants of the era were applied with the older style oil and grease cups. This method produced a feast or famine condition for the bearing. To solve this all or nothing-at-all problem, the automatic pressure feeding cup was introduced. But the constant pressure supplied by the spring in this type cup, combined with the restricted orifice at the outlet, caused many of the marketed greases to bleed or separate; when this occurred, the cup became loaded with a cake of hard soap that prevented further delivery of lubricant to the bearing. Special cup greases were developed and before long their limitations became quite apparent. Cup greases were not universally suitable for all points being lubricated in the mills: this failing caused many lubrication problems to remain prevalent throughout the industry.

. . . . plant-wide distribution of bulk grease would reduce handling problems and permit utilization of more adequate lubrication programs . . . .

Another application method was introduced to the plants in this same decade: the pressure hand gun and fitting which permitted improved lubricants to be applied. Before long the use of this equipment was widespread. However, the method had its shortcomings; machines had to be shut down in order to lubricate the bearings as a risk to the oiler was involved if the machine was to be lubricated while in operation. For the oiler's safety, the fittings were grouped in a central location. But the central arrangement proved unsatisfactory for lubrication purposes since it offered no accurate control over the amount of lubricant dispensed; the amount dispensed was entirely dependent upon the human elements of judgment and experience. At this time the greases offered for mill consumption were supplied in containers of all shapes and sizes.

In the early 1930's centralized lubrication systems came of age. With an increasing number of installations, the volume of hand oiling declined until, in 1945 the use of black oils became obsolete in steel mills. Black oil was being replaced by an array of various base-soap greases in the interim of the early 1930's and the mid-1940's. In this period measured amounts of grease could be dispensed to bearings that required the same type lubricant. Nevertheless, the in-plant problems of handling the grease drums still remained. In addition the plants now had to contend with an inventory problem that was created by the variety of greases in use.

At this point two significant developments occurred in the lubrication field. The first major break-through

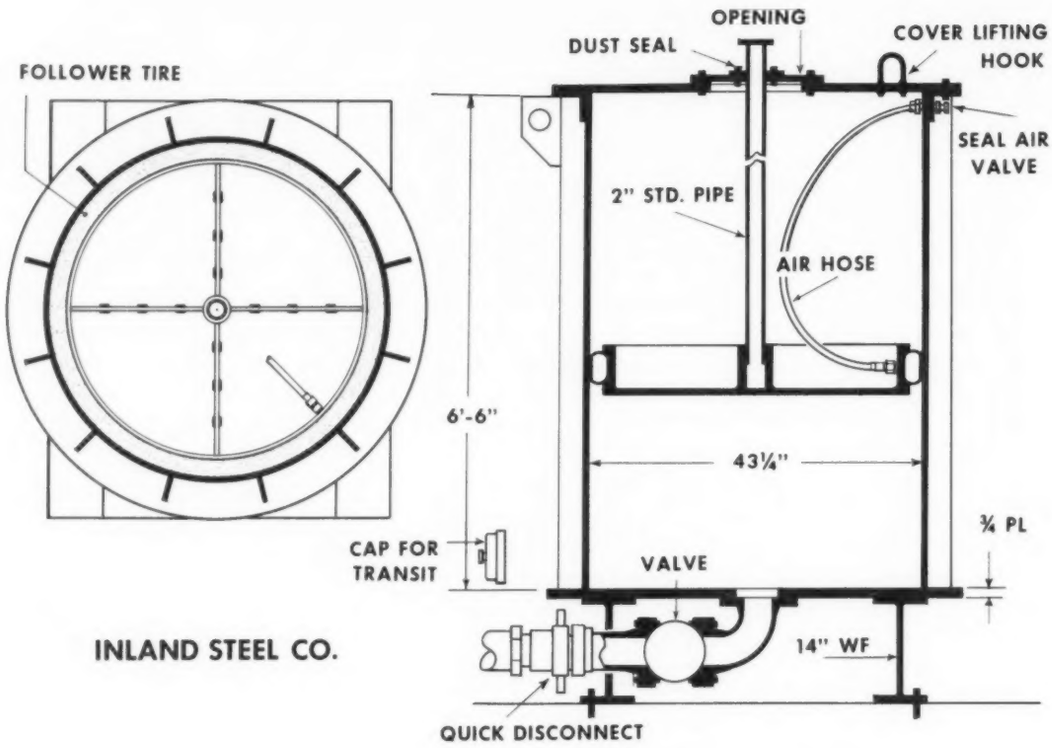


Figure 1 — A follower plate with an inflatable seal was used to make certain removal of the maximum amount of grease.

in steel mill lubrication was the introduction of multipurpose greases. The second was the acceptance of the standardized 400-lb container. As a result of these developments, relatively large quantities of grease with a wide range of applications could be purchased in a standard container. The plants' inventory and storage problems were eased somewhat. But neither development eliminated the plants' need of moving the grease from central storage to the consuming departments. Additional problems arose in both central and departmental storage since most oil houses were not designed for central drum storage, nor were the drums readily adaptable to good housekeeping in the consuming departments. Several other problems were incurred: (1) a separate department had to be operated for the collection and disposal of drums; (2) the plants had to write off the waste incurred by residuary grease since five to ten per cent of the grease frequently remained in the bottom of the drum; (3) the over-all lubrication cost had to include the cost of the drum as a contributing factor.

BULK CONTAINERS

The steel industry has resolved many in-plant problems dealing with grease storage and transportation by applying modern concepts of materials handling. These concepts, based on ease and economy as applied by the plants, have led to the development of bulk grease handling. Rather than designing an installation for the entire plant, most of the early installations for bulk grease handling were designed to service a particular operation or department. Since each plant had to resolve its own problems, a number of container designs as well as handling methods have been developed. In most instances both developments were the result of a cooperative venture between individual plants and their suppliers, although frequently the plants developed their own containers and then cooperated with suppliers to work out delivery methods.

The first bulk grease handling facilities were installed in a universal slabbing mill of the Inland Steel Co. In this installation, three 4000-lb portable containers are manifolded in central storage. A container (Figure 1) 4 ft in diameter by 6½ ft high was fabricated from ⅜-in. steel plate, reinforced with steel ribs: the bottom is ¾-in. plate. To allow clearance for the valve and piping, the tank is mounted vertically on flange beams 14 in. wide. The entire assembly, with the exception of the cover, is welded together to form a single unit, and a ¾-in. plate cover is bolted into position. The interior wall of the tank is sand blasted to a bright finish. A special feature on this tank is the buoyant pneumatic follower plate. An inflatable seal on the follower plate enables atmospheric pressure to provide positive pump prime; the seal also wipes the tank walls clean during each emptying cycle. The 2-in. pipe, used as a guide and level indicator, is removed when shipping a filled container. Containers are filled and emptied through a single line and valve on the bottom of the tank. At one time the tanks were taken from the building through removable hatch covers, placed on a flat-bed truck and taken to the supply source. Of the three containers used in this manner on the installation: one was used for operating purposes; a second was a stand-by reserve; and the third when empty was released to the supplier for refilling.

One of the first bulk containers used at U. S. Steel Corp.'s Gary Sheet and Tin Mill was a square one fabricated by their roll shop. Of a more recent design is the round, portable tank with a 5000-lb capacity, see Figure 2. This tank has a diameter of 54 in., a height of 60 in. and the stand is 30 in. high. An air-driven grease pump is mounted on top of the container; an elongated tube is attached to the pump in order to pump out the grease from the bottom of the container. This tank design does not incorporate a follower plate since experience has shown that no residuary grease remains in the container if the container is jarred slightly. A

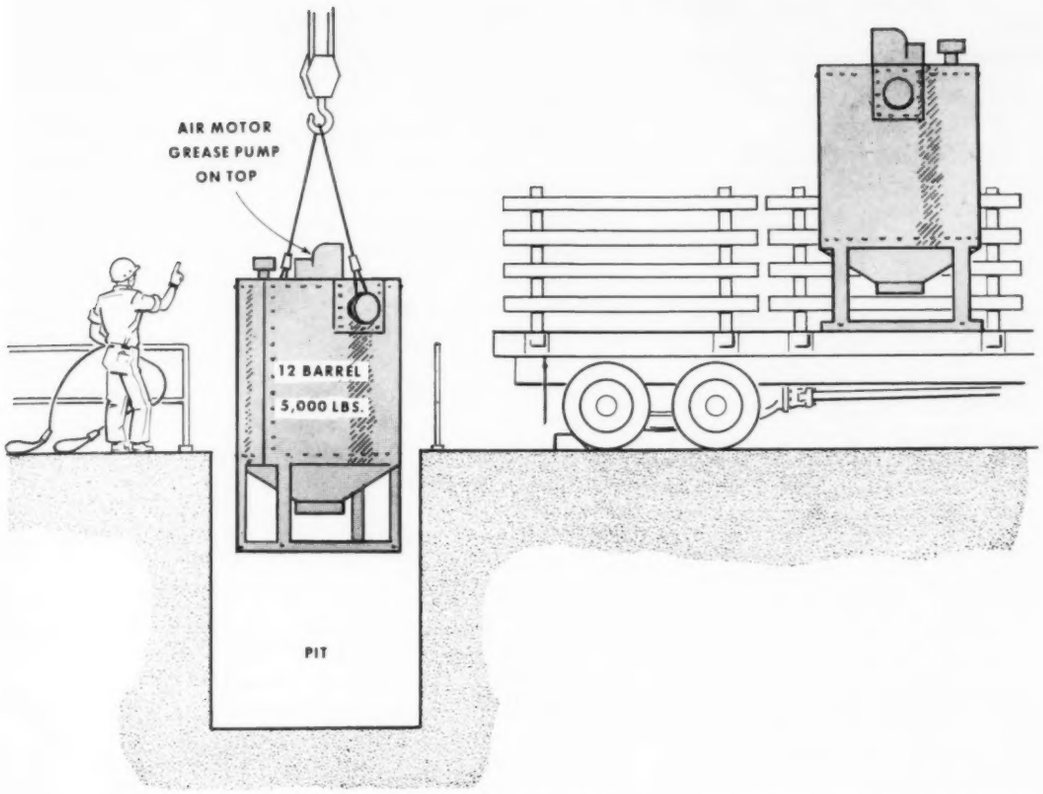


Figure 2 — Pit storage of stand-by grease containers would free needed floor area.

crane is used to move containers from the truck bed into central storage. As one container of grease is consumed by a department, another container is moved into position to replace it. Presently the containers are stored in the roll shop, but pit storage is being considered as a means of gaining additional floor space. Since they are portable the containers are weighed upon entering and leaving the plant, and the plant receives credit for any residuary grease in the container when it leaves the plant.

A stationary container resembling a grease maker's kettle (Figure 3) is used at U. S. Steel's Gary steel works. The tank with an 84-in. diameter and a height of 96 in., has a capacity of 20,000 lb. The base stand is 45 in. high. Although never used a 1-rpm gear-driven agitator was included in the design to remove any air entrained in the grease during the filling process. It was thought that the agitator would also prevent oil separation during prolonged storage and provide a homogenous blend at all times. This container is filled from the top and a manhole in the cover is used for inspection purposes. Grease is delivered to the plant in two 18,750-lb transport containers carried on the bed of a tractor trailer. Both transport containers have a follower plate and, therefore, are filled and emptied from the bottom. A gear-type pump is used to transfer grease from the transport to the stationary containers in central storage. The weight of the delivered lubricant is recorded by a direct-reading control panel connected to a load cell. Grease from the plant's containers is delivered into a 2-in. header line by air-operated pumps angled into the bottom of the containers.

The general favor and the experience gained from the two bulk grease installations within the corporation prompted a standardized design for such containers. In order to meet the needs of the various plants, it

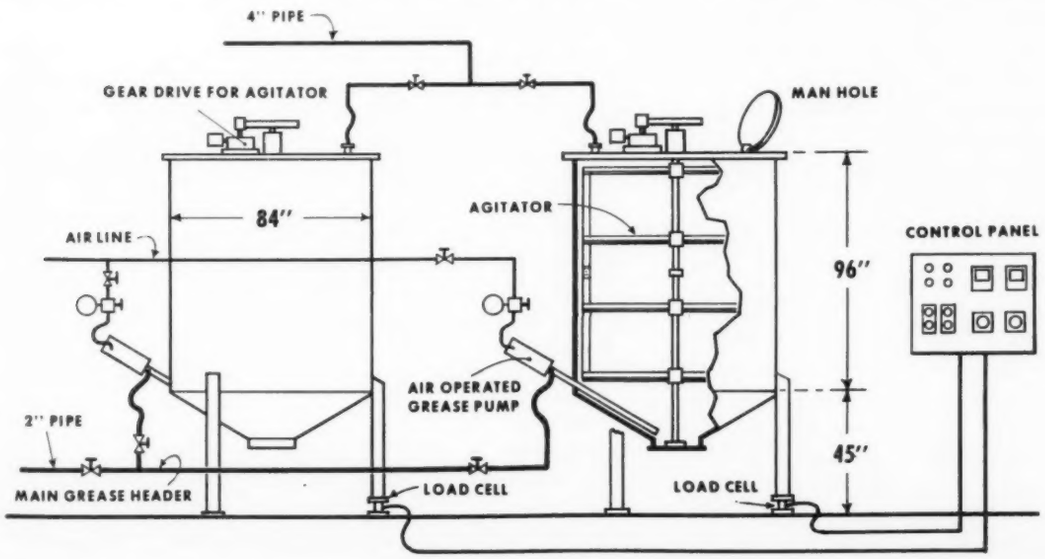


Figure 3 — The weight of the grease delivered is automatically recorded on a control panel connected to load cells contained in one of the legs of each tank.

TABLE I
Standard Design Containers

Capacity		Dimensions			Wall type
Lbs.	Cu ft.	Diameter, ft-in.	Height, ft-in.	Stand, ft-in.	Plate thickness, in.
3,300	60.2	4-6	3-10	2-0	$\frac{1}{4}$, $\frac{1}{8}$ and foam
10,000	186.5	6-0	6-0	3-0	$\frac{1}{4}$ and $\frac{1}{8}$
20,000	362.0	7-0	8-9	3-3	$\frac{1}{4}$

was decided to fabricate containers in three capacities; one would be portable and two would be stationary. As finished products, the portable container has a capacity of 3300 lb, and the two stationary containers have capacities of 10,000 and 20,000 lb, see Table I. The decision to make both portable and stationary containers was determined by a great number of factors but foremost was the desire to fill the requirements of individual plants. Therefore, the capacities of these containers met the general consumption requirements of small, intermediate and large operations. The size of the portable container was greatly influenced by the standards set for transportation purposes. With a diameter of 4 ft-6 in., a height of 3 ft-10 in., and a stand height of 2 in., the portable container can be shipped economically by barge and railroad. In addition the container can be packed efficiently on truck beds. The standard portable container is fabricated from $\frac{1}{4}$-in. plate, but to hold down the gross weight of the tank, the portable container may be fabricated from either $\frac{1}{8}$-in. plate or a foam construction. Two wall thicknesses were used in order to permit flexibility with regard to insulation and sturdiness. The two larger containers were designed for permanent installation within a plant.

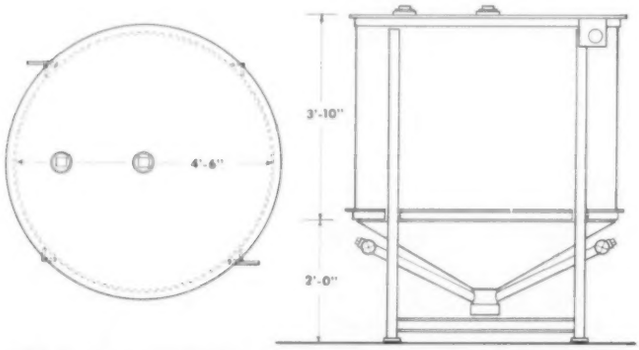
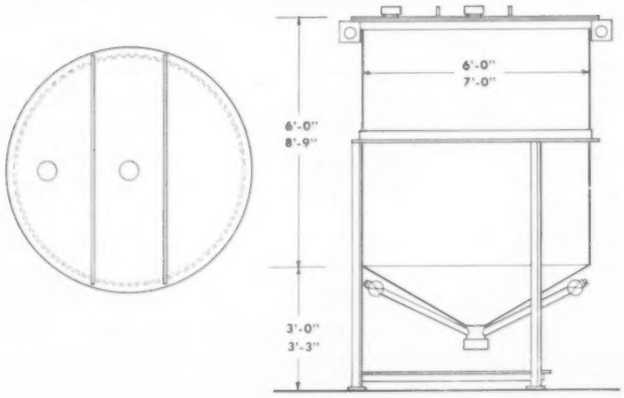


Figure 4 — A portable container was designed with regard to the various handling equipments available.

Figure 5 — Stationary containers of the suggested design have capacities of either 10,000 or 20,000 lb.



The capacities of these stationary containers were determined through experience as well as through the establishment of grease requirements for particular operations or mills.

The 3300-lb standard design container (Figure 4) was set up as a standard only after discussion with lubrication engineers and oil company representatives. The capacity of the portable container was established to conform with transportation, insulation and handling requirements. Since the small container was to be portable, it was necessary to fabricate the container so that it could be handled efficiently with a fork lift as well as a crane. With this in mind the gross weight of the container permits existing lift equipment to be used. In the event the container is to be moved by a crane lifting hooks have been included. As an optional feature a pneumatic booster-type pump can be added to the base of the container and pumping rate with this type pump averages 40 cu in. per min up to the full line pressure.

Standard design 10,000 and 20,000-lb containers (Figure 5) have the same basic design as the portable unit. On the larger containers certain optional features have been incorporated on the basic design. Among these are a low rpm agitator system, a spring loaded cell and vents. If deemed necessary by any plant a follower plate may be incorporated. The interior wall of a standard design tank may either be sand blasted to a bright finish or treated with chemically resistant paints such as an epoxy resin. Toward gaining more experience and a further acceptance of the standard design, planned shipments of the portable container with both foam and plate construction will be made. In this fashion additional information will be accumulated on the necessary strength requirements for handling containers between a plant and its supply source. The final result of standard engineering for bulk grease containers is a cost reduction by eliminating the need for individual engineering on each installation.

A major oil company has proposed a square design tank, see Figure 6. With this design the width is approximately 42 in. and the height is 5 ft. A stand on this tank would be 12 ft high. The container would incorporate a follower plate, a flat bottom and a top opening for inspection. This container would be bottom loading and have a capacity of 3300 lb.

It is interesting to note that the American steel industry was not alone in developing bulk grease facilities. At the Margam works of the Steel Co. of Wales, bulk grease facilities were installed on a sintering plant in the spring of 1959. Two cylindrical storage tanks (Figure 7) are mounted on six 8 ft-5-in. trestles, and each tank is heated by 4-in. steam coils. A ladder and overhead walkway provide for an easy inspection of these top loaded tanks. One tank holds 28,000 lb of lubricant while the other holds 30,000 lb. A tank truck loads the permanently installed tanks through a 3-in. supply line, the minimum refill load being 22,400 lb.

BULK DELIVERIES

The bulk delivery of lubricant may be accomplished through a variety of means. As examples we offer the following delivery means, either currently practiced or soon to be inaugurated. A special truck bed holding multiple tank units may be used to deliver grease to

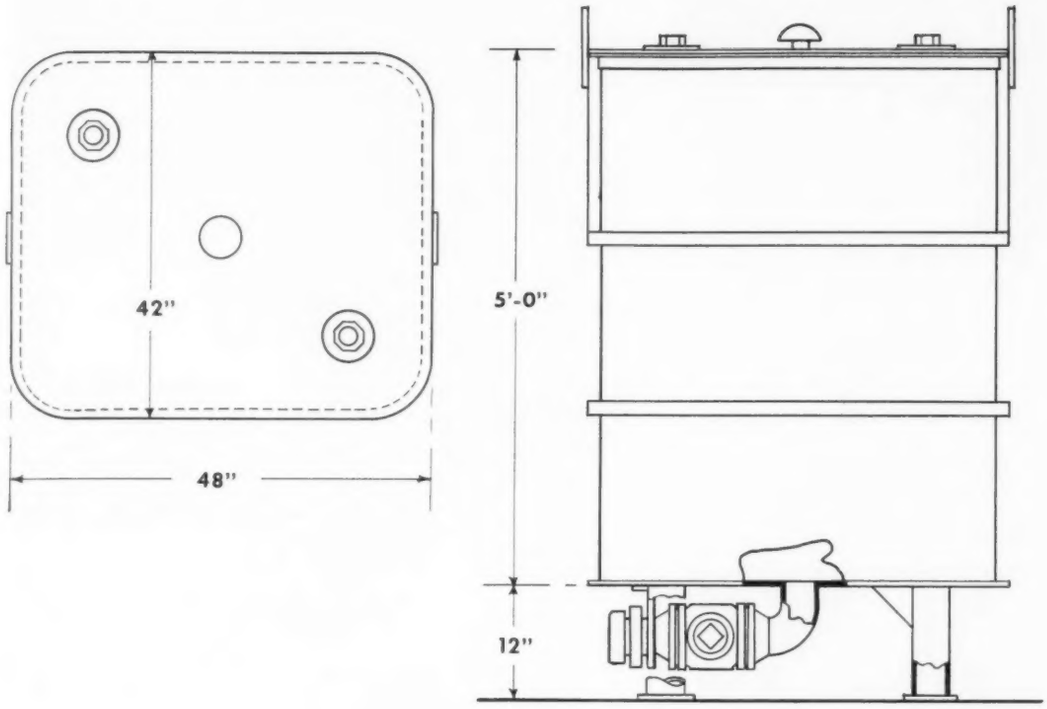


Figure 6 — A standard design for a portable bulk grease container has been proposed by a major oil company.

permanently installed tanks within a plant. The truck is so designed that a special pumping unit is used to empty the tanks on the truck bed. Since the truck-bed tanks have a follower plate, they are bottom emptying. Along the same line, a bulk tank truck may be used to deliver lubricant to permanently located tanks of various sizes scattered throughout a plant; in essence, this becomes a door-to-door type delivery.

Portable containers placed on a flat-bed truck may be used for the bulk delivery of grease to a plant, see Figure 8. These containers could be filled at a distant point and shipped by barge or rail to the local supply source, where they would be transferred to the truck bed. Containers used in this fashion could incorporate a pneumatic transfer pump, built into the base of the container, to move the grease to the plants' containers, for this would eliminate the need of equipping a truck with special pumping equipment. The air for operating this pneumatic pump would be supplied by the plant. Approximately six to eight containers could be placed on a truck bed if they were staggered.

Rubber collapsible containers are currently marketed for the transportation and storage of bulk materials, see Figure 9. Since these containers are collapsible for return, have a low tare weight and can be handled without too much difficulty, they readily lend themselves to the bulk transportation of grease. The containers are supplied in capacities ranging from 50 to 370 cu ft. One such marketed container is fabricated from several layers of cord fabric and synthetic rubber vulcanized into one piece; this construction is comparable to that of a sidewall of a tire. Steel cables are spaced through the interior to provide extra strength for handling and transportation purposes. A proposal has been made to the effect that these rubber fabric containers may also be used as storage containers within the plant. If they are to be used in this fashion, special holders are necessary to accommodate them, see Figure 10. This particular type of a holder has six hydraulically operated fingers that aid in emptying the bag, literally squeezing grease out of the bag. To use the rubber fabric container in this arrangement for bulk grease would seemingly offset the savings incurred by 2-way transportation due to the initial investment involved or the demurrage on a rented unit.

Figure 7 — At least one European steel company has installed bulk grease handling facilities.

This discussion regarding containers and delivery means is not intended to infer that the 400-lb drums are outdated, rather it is meant to point out the advancements made by the industry in bulk grease handling. Surely it is realized that not all plants or operations are either geared for or demanding of bulk grease installations; some departments must still maintain special greases or have low consumption rates that could not possibly justify bulk facilities. For these plants the 400-lb container is still the most acceptable and feasible container. Transportation wise it should be stated that a number of 400-lb containers can be transported to a mill on the same vehicle that delivers grease to bulk containers. This means that a combination of containers is practical for both handling and delivery; also it means that each plant can maintain the number of greases necessary to its individual operations.

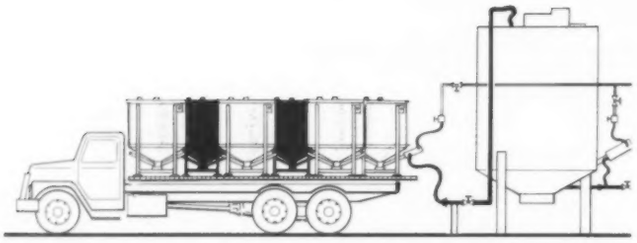


Figure 8 — Portable containers could be used to transport grease over large distances, either with truck or barge.

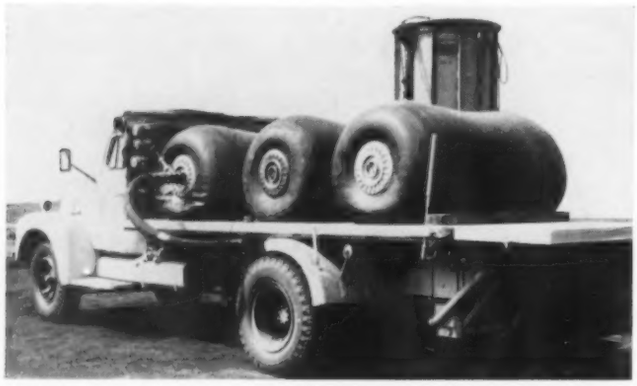


Figure 9 — Collapsible rubber containers are available for transportation of bulk materials.

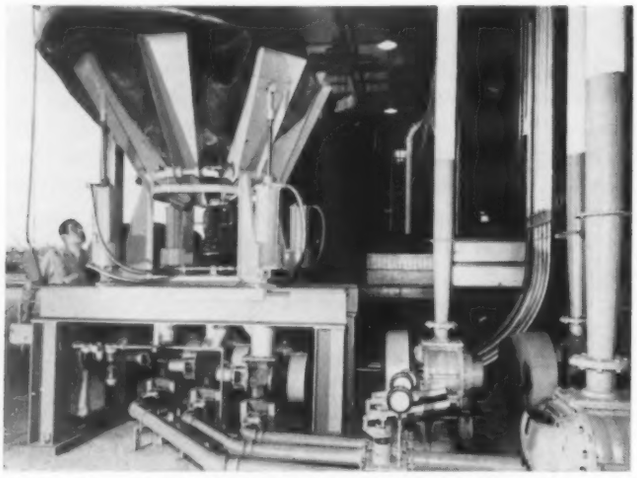


Figure 10 — Special handling facilities would be required to assist in emptying the rubber containers.

MILL UTILITY-ITEM

Bulk handling facilities were coincidental to and not dependent upon the development of a new class of grease, generically termed black lithium. Before going further it should be pointed out that bulk grease containers and delivery means could have been employed for roll neck greases of the calcium and graphite type but the limiting factor would have been the narrow range of applications possible with this type of a grease. The black lithiums have widened the range of applications readily lending themselves to dispensing means. At the same time they have proved themselves economically.

Developments in lubricants, application methods, bulk containers and delivery means have led us to our present position. At this time it becomes necessary to further develop these innovations toward the economic and efficient betterment of mill operations. To this extent the proposal is now made that grease be made a mill utility-item. Basically this consists of placing a header line reaching each and every department throughout the plant. In order to accomplish this feat of pumping over such great distances, a pneumatic in-line booster type pump (Figure 11) may be used. With the use of this in-line pump, it is feasible to pump distances of approximately 5000 ft, if a pump of this type is inserted at approximately every 700 ft. A minimum of 2000 psi can be expected at the end of the 5000-ft line. Even through extremes of temperature this pressure is adequate to operate a system.

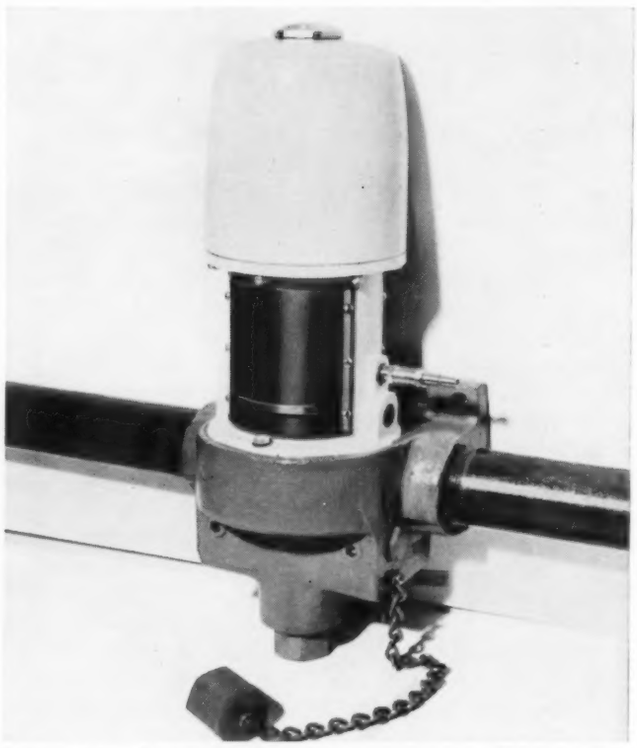


Figure 11 — Pneumatic booster pumps permit pumping distances of up to 5000 ft with a minimum final pressure of 2000 psi.

The proposal of making grease a mill utility-item does not imply that entirely new construction must be placed into each and every plant. It is still practical and economical to use existing systems or to modify these facilities. From the header line leading out of a bulk container, existing reservoirs on centralized systems could be filled; or the branch line, with adequate valving, could feed directly into a measuring device; or the branch line could feed into hose reels, see Figure 12. The use of any combination of new, modified or existing facilities would enable grease to be accessible in any part of any plant. If made a utility-item, grease is virtually on tap!

SUMMARY

The use of any of the innovations in bulk grease handling and dispensing enables a steel mill with either a high or relatively low consumption to show intangible benefits as well as real ones. The use of standardized containers permits the conservation of floor space and automatically increases safety within a plant. It also reduces the chances of contamination and improves housekeeping while eliminating the time necessary to warm up 400-lb containers. An entire installation for

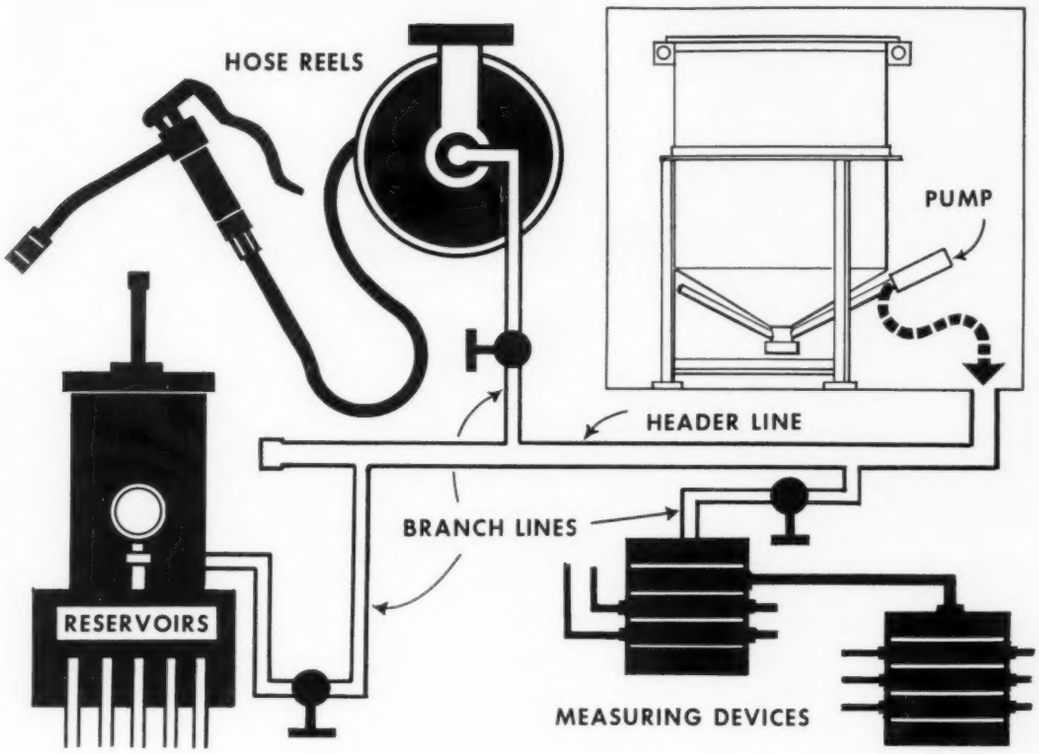


Figure 12 — Many methods of dispensing grease can be fed from a central bulk container.

bulk grease handling and dispensing would certainly reduce lubrication and operating costs. An additional benefit would be shown through the reduction of residuary materials. In essence it can be said that a grease kettle to bearing lubrication method offers the optimum in handling of materials.

Discussion

PRESENTED BY

FRANK L. GRAY, Lubrication Engineer, Gary Steel Works, United States Steel Corp., Gary, Ind.

J. G. SPARKS, Manager, National Sales, Cities Service Oil Co., Chicago, Ill.

M. M. GURGO, Sales Service Coordinator, Esso Standard, Div. of Humble Oil & Refining Co., Pittsburgh, Pa.

Frank L. Gray: Gary steel works has two systems in operation, one under construction, one scheduled for installation, two out of engineering and three in engineering. The first four installations in this program will be supplied by four different grease plants, each with a different grease and each with a different system of bulk delivery. All methods fulfill the basic requirement of bulk delivery to a fixed container.

The size of the bulk grease container in a fixed position is governed by a 30-day consumption and a minimum shipment that will permit the grease manufacturer to deliver the total amount of grease that has been prepared in his grease kettle.

Our 46-in. mill has been designed for high consumption and the maximum grease delivery. Our coal handling system is designed for a minimum usage and minimum delivery. Every system will have its individual characteristics and can be supplied in the required amounts by the grease manufacturers with the equipment now available.

J. G. Sparks: Probably the most important item to be considered in both grease handling from a supplier's standpoint is the type of grease needed for a given application. The point of delivery to plant storage is not critical due to the ability of present-day power equipment to deliver the product to the storage tanks.

Grease temperature in unloading has not been a factor as grease has been unloaded at ambient temperatures of 0 F. Container sizes within a plant present no problem to the supplier so long as a full truckload of grease can be received by the plant at one time.

M. M. Gurgo: Until recently bulk handling has ended by filling various sized containers, the 400-lb drum being the largest in most cases. Now with the work pioneered by the steel industry, the benefits of bulk grease handling can be extended to others.

The author has proposed both permanent and portable methods. The method that will bring the most benefit is the one that is permanently installed and capable of handling the maximum amount that can be transported. At present over the road weight limitations in certain states restrict this to around 30,000 lb. There are many locations where requirements will only justify installation of smaller storage tanks. To accommodate these requirements, special equipment is required to eliminate contamination and to permit "drop off" deliveries of smaller quantities to customer owned receivers.

Benefits from this type of installation and use have been mentioned. The obvious areas all reflect greater economics, or expressed another way, lower lubrication costs. These economies can come from many areas such as reduced labor costs in handling and applying lubricants, less lubricant lost in containers, lubricant cost reduced by elimination of containers, extended equipment life and reduced ordering and inventory procedures to name a few. ▲

Design and Operation of

by V. O. SOROKIN
Senior Engineer
Large Rotating Apparatus Dept.
Westinghouse Electric Corp.
East Pittsburgh, Pa.

. . . . proper regulation of inter-stand tension is an important factor in the cold reduction of strip in multi-stand mills. . . .

TENSIOMETERS are used to indicate or to regulate the tension between stands of tandem cold, hot strip or temper pass mills. They act on the principle of spring scales, measuring the vertical component of force in a strip as it moves over the tensiometer roll.

An indicating tensiometer gives the mill operators a continuous visual indication of tension by means of a dial. If the tensiometer's output is automatically applied to controls that regulate the tension between stands of the mill, it is called a regulating tensiometer.

Controlled tension between the stands is necessary since excessive tension will break the strip, and loss of tension may cause loops between the stands. The proper amount of tension will keep the strip centered on the rolls of the mill.

By the combined action of roll pressure and tension, strips are rolled flat, without wrinkles, to the proper thickness. The amount of tension required depends on the product being rolled.

To measure tension the tensiometer roll is placed above the mill pass line so that the strip passes over it at an angle. This deviation from horizontal causes downward forces of strip tension which are used to deflect a spring supporting the tensiometer roll. For the sake of easy threading of the coil through the rolls, the amount of deflection is kept small.

Another reason for having only a slight strip deviation is to limit vertical components of strip tension to a low value. Thus, even if the strip tension is high the springs needed to measure it do not need to be large. Figure 1 shows a schematic diagram of an installation of tensiometers.

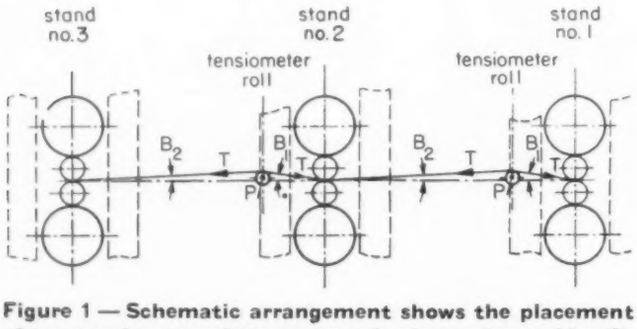


Figure 1 — Schematic arrangement shows the placement of two tensiometers between stands of a tandem cold mill.

Figure 2 — Summations of the forces acting on the tensiometer roll permit the determination of calibration curves.

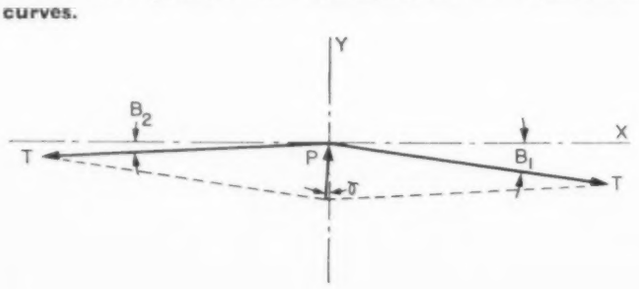


Figure 2 is a diagram of forces acting on the roll. To calibrate tension indicators, it is necessary to know the relation between the tension in the strip (T) and the force (P) acting on the tensiometer roll. If inertia forces are neglected, and if the strip is considered perfectly flexible, two equations can be obtained by projecting the forces on two axes:

$$x: -T\cos B_1 + T\cos B_2 - P\sin\gamma = 0 \quad (1)$$

$$y: -T\sin B_1 - T\sin B_2 + P\cos\gamma = 0 \quad (2)$$

Dividing equation 1 by equation 2 and converting:

$$\frac{\cos B_1 - \cos B_2}{\sin B_1 + \sin B_2} = \frac{-2\sin\left(\frac{B_1+B_2}{2}\right)\sin\left(\frac{B_1+B_2}{2}\right)}{2\sin\left(\frac{B_1+B_2}{2}\right)\cos\left(\frac{B_1-B_2}{2}\right)} = -\tan\gamma \quad (3)$$

$$\tan\left(\frac{B_1-B_2}{2}\right) = \tan\gamma \quad (4)$$

$$\gamma = \frac{B_1-B_2}{2} \quad (5)$$

Tensiometers

Substituting the value for γ into equation 1:

$$-T(\cos B_1 - \cos B_2) = P \sin\left(\frac{B_1 - B_2}{2}\right) \quad (6)$$

Then converting:

$$2T\left[\sin\left(\frac{B_1 + B_2}{2}\right)\sin\left(\frac{B_1 - B_2}{2}\right)\right] = P \sin\left(\frac{B_1 - B_2}{2}\right) \quad (7)$$

From this the force P:

$$P = 2\,T \sin\left(\frac{B_1 + B_2}{2}\right) \quad (8)$$

This equation gives a relation between the force deflecting the springs and the tension (T) in the strip, and it is used for making calibration curves for tension-indicating voltmeters.

The output of magnetic transducers, which measure spring deflection, is proportional to the roll deflection. Knowing this deflection and the spring constants of cantilever springs, P can be calculated. Therefore, the above equation is used to find T.

All tensiometers in a tandem mill are interchangeable and a spare can be used in any location. To take care of tension difference between stands, the tensiometers are set to different heights above the pass line. Where tension is high, the position of roll is lower so that the resultant force deflecting the springs is essentially the same in all stands.

Tensiometers can be made for any required tension capacity. Currently, tensions up to 200,000 lb are being measured. Roll width varies from a few inches to ten ft.

To design a tensiometer that will perform satisfactorily, despite the very adverse operating conditions of dirt and water, represents an engineering challenge.

Figure 3 shows a typical installation of indicating tensiometers in a 4-stand tandem cold mill. Tension-indicating instruments are mounted on the control panels at the level of the operator's head.

The hot rolled, pickled coiled strip is brought into the mill and is wound on to the reel visible in the left hand side of Figure 3. Tensiometer rolls are located between stands with the top of each roll protruding slightly above the mill pass line. The operators read the tension on the panel instruments and correct it to the desired

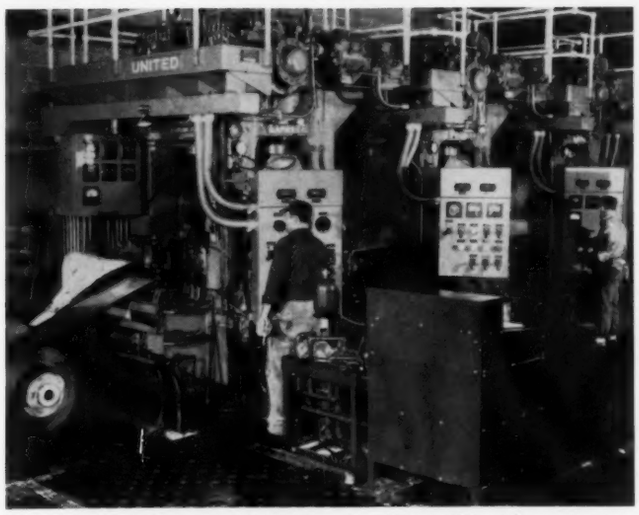


Figure 3 — Inter-stand tension is adjusted by the operator during rolling.

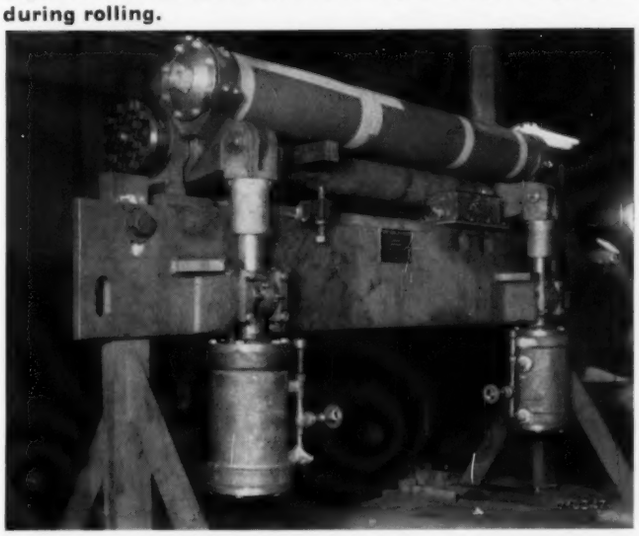
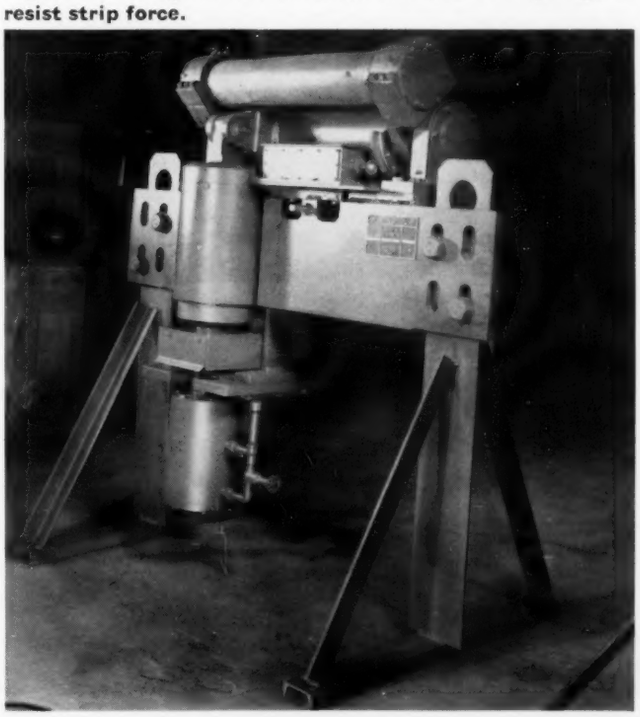


Figure 4 — Synchro-tie transmitters and receivers have been used with torsion-bar design to give a read-out at the operator's desk.

Figure 5 — Large travel tensiometers use coil springs to resist strip force.



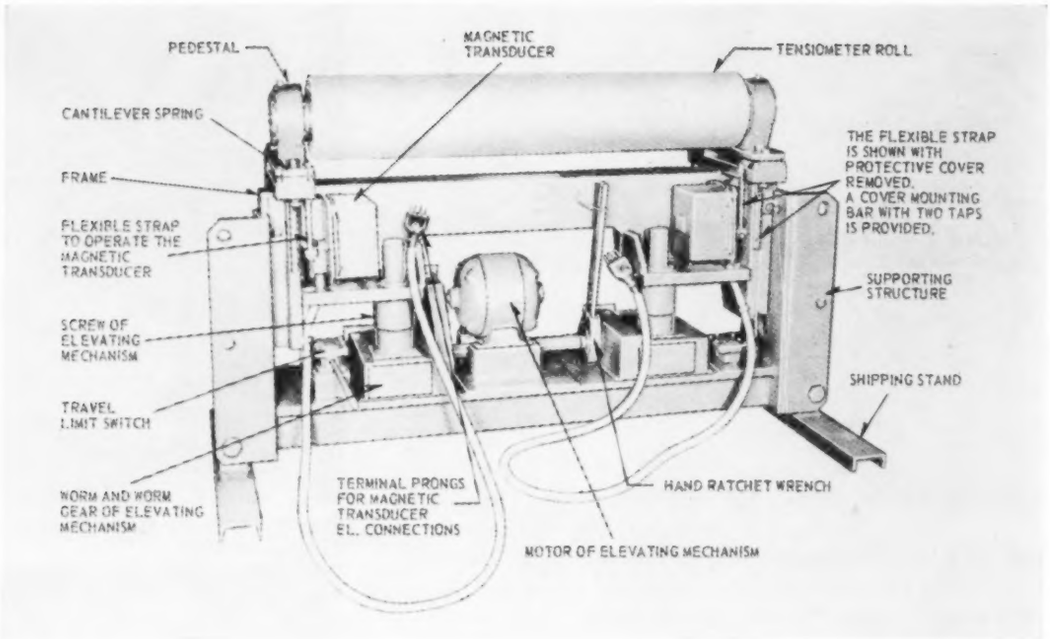

PEDESTAL
MAGNETIC TRANSDUCER
TENSIOMETER ROLL
CANTILEVER SPRING
FRAME
FLEXIBLE STRAP TO OPERATE THE MAGNETIC TRANSDUCER
SCREW OF ELEVATING MECHANISM
TRAVEL LIMIT SWITCH
WORM AND WORM GEAR OF ELEVATING MECHANISM
TERMINAL PRONGS FOR MAGNETIC TRANSDUCER EL. CONNECTIONS
THE FLEXIBLE STRAP IS SHOWN WITH PROTECTIVE COVER REMOVED. A COVER MOUNTING BAR WITH TWO TAPS IS PROVIDED.
SUPPORTING STRUCTURE
SHIPPING STAND
HAND RATCHET WRENCH
MOTOR OF ELEVATING MECHANISM

Figure 6 — Magnetic transducers can be used to initiate roll movement signals.

value by adjusting the speed of motors with motor-field rheostats.

The highest tension is between the first and second stands and it gradually diminishes toward the delivery end of the mill. The strip thickness diminishes and the strip speed increases during the process.

Regulating tensiometers automatically control tension in the strip by regulating the speed of the mill motors. In the past the practice was to use indicating tensiometers on multi-stand continuous cold mills and the regulating tensiometers in 2-stand temper pass mills. Lately, in combination with automatic gage control, automatic tension control is applied to the multi-stand continuous mills using regulating tensiometers.

In the design of tensiometers, types of springs used are leaf, coil and torsion springs. To indicate tension, synchro-tie transmitters and receivers have been used on some installations along with many different designs of variable reluctance transformers connected to voltmeters.

Figure 4 shows a large-travel torsion-bar tensiometer. A synchro-tie transmitter connected to a receiver mounted on operator's panel indicates tension. In some installations it was considered advantageous to use the tensiometer as a looper, a cushion to absorb fast changes in tension. However, practice did not show much difference in strip breakage if travel was decreased. Synchro-tie transmitters performed well in service even when they were located in positions where they were subjected to oil and water spray.

Figure 5 shows a coil-spring large-travel tensiometer. This type is now used instead of a torsion-bar unit for large-travel tensiometers. A synchro-tie transmitter and receiver are used for tension indicating. The upper cylinder contains the coil spring, the lower cylinder is an oil damper.

No height adjustment mechanism is used. Because of the large elevation of the roll above pass line, the change of mill-pass-line position constitutes only a small percentage of the total height of the roll above the pass line. Therefore, the error introduced can be neglected.

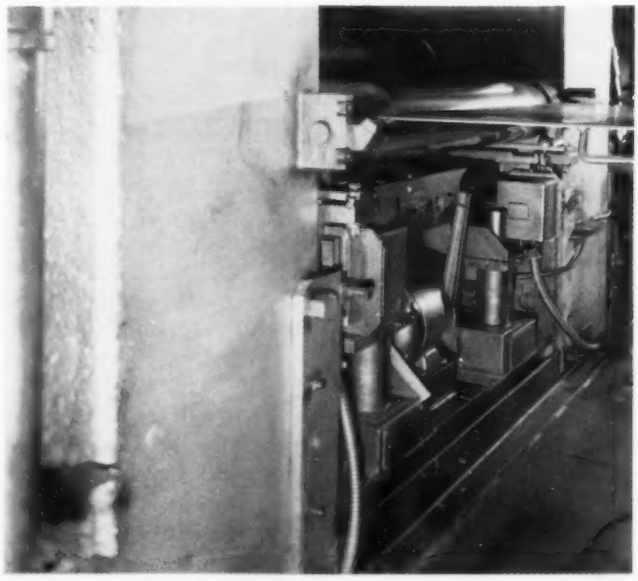
In most applications, the design shown in Figure 6 can be used. It is a small-travel tensiometer, and the roll is mounted on cantilever springs.

Figure 6 shows a current design which consists of deflector roll, pedestals, cantilever springs, frame supporting structure bolted to the mill, reversing elevating mechanism and two magnetic transducers. Cables connect the transducers to indicating instruments. Figure 7 shows a tensiometer in operation installed in the mill.

The magnetic transducers are variable reluctance transformers with a rotary core. There are two stator coils of opposite polarity and one rotor coil. When the core is in its center position, the magnetic circuit reluctance of the stator coils is identical. Since the coils are of opposite polarity, the flux linking the rotor coils is zero and the rotor coil is not energized, see Figure 8.

When the core is shifted from its neutral position the symmetry is lost and the flux of one coil is larger than the flux of the other. This flux energizes the rotor

Figure 7 — The tensiometer is installed on the exit side of the mill stand.



coil and its rectified output is fed into the instrument which registers deflection.

A schematic diagram of the tensiometer and control circuit is shown in Figure 9. This diagram shows the roll of the double-ended tensiometer, in its pedestals, assembled on cantilever springs. Movement of the roll is transmitted to the levers mounted at the ends of the magnetic transducers. When tensiometer roll is in its neutral position, the transducers are adjusted so that their output is zero.

During operation the vertical component of strip tension deflects the roll on its springs. The motion is transmitted by flexible straps (to eliminate wearing points) to the magnetic transducers. The a-c output of the transducers is applied to rectifiers. The tension indicators are d-c voltmeters calibrated in lb of tension. The indicator T indicates the total tension and the indicator D showed the differential tension.

Adjustable resistors in series with the voltmeters are used to adjust the meters. The magnetic transducers are designed to provide trouble-free service in the field.

The rotor is mounted in preloaded, tapered roller bearings. The bearings are assembled in brackets so that clearance, due to wear of the bearing, is eliminated by spring action of the bracket. In this manner, the calibration of the device is maintained.

To prevent entrance of moisture, leads are brought from the magnetic transducer through a packing gland. Neoprene covered cable protected by a steel flexible cover connects the transducer to the tensiometer control cabinet.

Figure 10 illustrates the magnetic transducer with the cover removed. The magnet head, the stator and the rotor are mounted on a plate. The plate has a welded mounting lug and the terminal outlet block with packing gland. A "bread basket" cover and a neoprene gasket seal the assembly.

A seal is provided around the magnetic transducer shaft to prevent entrance of water and oil. This seal consists of two seal rings, and the space between them is filled with a water repellent grease. A fitting and a relief valve are provided so that grease chamber can be flushed.

The rotary-shaft-extension design has the advantage of reliable seals. Older plunger-type designs tended to pull water into the transducer enclosure because of variation of inside air pressure created by the deflection of diaphrams.

Power, through a constant-voltage transformer, required for the transducer is 15 watts, 115 volts, 50 or 60 cycles; or 275 volts, 400 cycles.

Instead of magnetic transducers, "load cells" can be used to measure the load.

Load cells are hermetically-sealed units which contain strain gages attached to steel bars. Load cells give an accurate reading, but their output is much smaller than the output of magnetic transducer. Therefore, an additional signal amplification is required.

One of the problems encountered in the operation of tensiometers is caused when the pass-line height is changed due to regrinding of the mill rolls. Since the component of tension force acting on the tensiometer springs depends on elevation of the roll above the pass line, the tension reading is not correct after regrinding.

Depending on the number of "billy" rolls used with

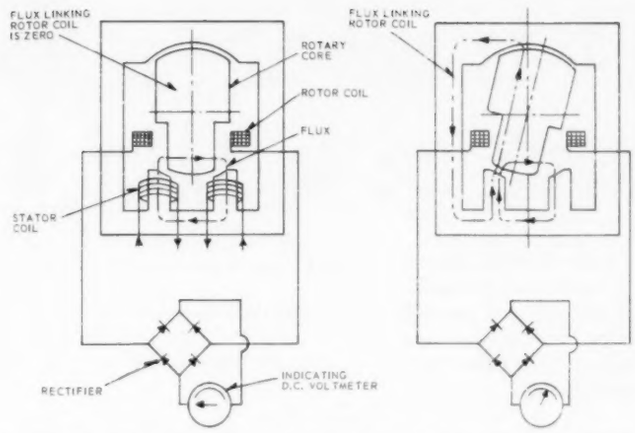


Figure 8 — Shifting of the core from its neutral position causes a change in flux relationship.

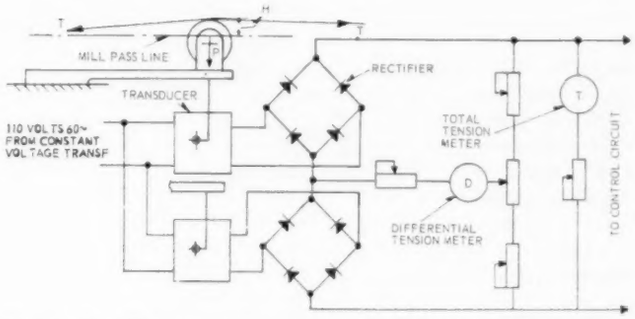


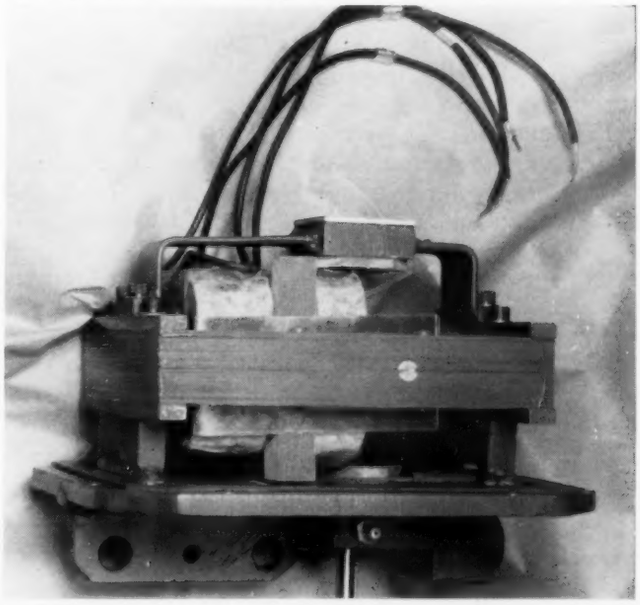
Figure 9 — Two d-c voltmeters calibrated in lb of tension indicate total and differential tension.

the tensiometer roll, one of the following means are used to insure correct readings.

When no billy rolls are present, a motor or hand-operated height-adjusting device and gages are used to reset the tensiometer roll to correct position, see Figure 11.

If a billy roll is set between the work roll of the stand and the tensiometer roll mounted on that stand, as shown in Figure 12, the amount of the change neces-

Figure 10 — The magnetic transducer is enclosed by a heavy cover and sealed with a neoprene gasket to protect it from accidental damage and keep out moisture.



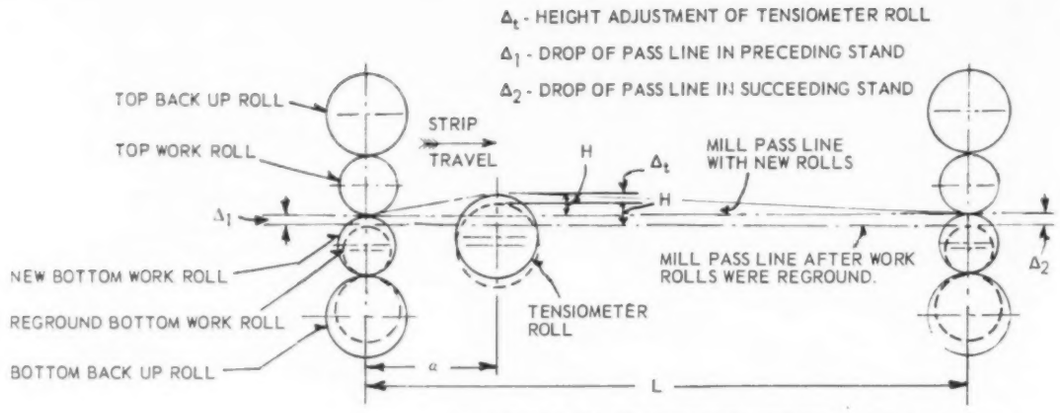


Figure 11 — A change in work roll diameter in either the preceding or succeeding stand changes the tensiometer pass line.

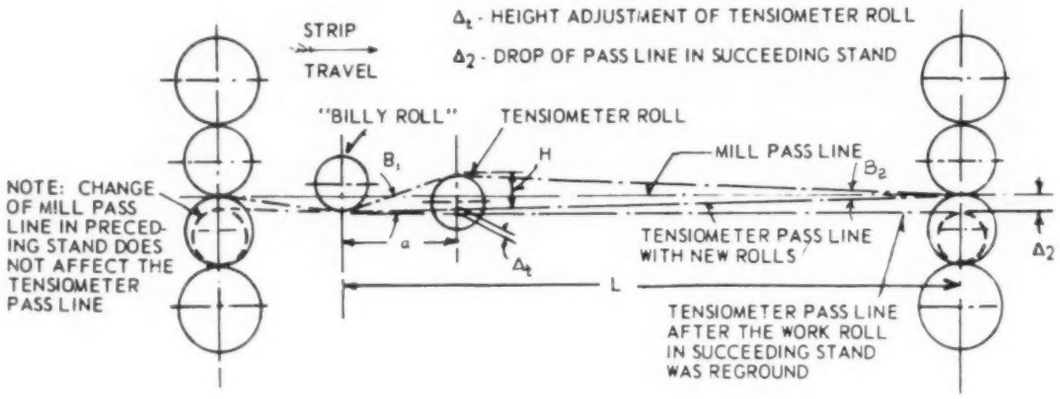

Δ_t - HEIGHT ADJUSTMENT OF TENSIOMETER ROLL
Δ_2 - DROP OF PASS LINE IN SUCCEEDING STAND
STRIP TRAVEL
"BILLY ROLL"
TENSIOMETER ROLL
B_1
H
MILL PASS LINE
B_2
NOTE: CHANGE OF MILL PASS LINE IN PRECEDING STAND DOES NOT AFFECT THE TENSIOMETER PASS LINE
a
Δ_t
L
TENSIOMETER PASS LINE WITH NEW ROLLS
Δ_2
TENSIOMETER PASS LINE AFTER THE WORK ROLL IN SUCCEEDING STAND WAS REGROUND

Figure 12 — Installation of a single billy roll will reduce the amount of adjustment required for a work roll size change in the succeeding mill and eliminate the need for adjustment after a work roll change in the preceding mill.

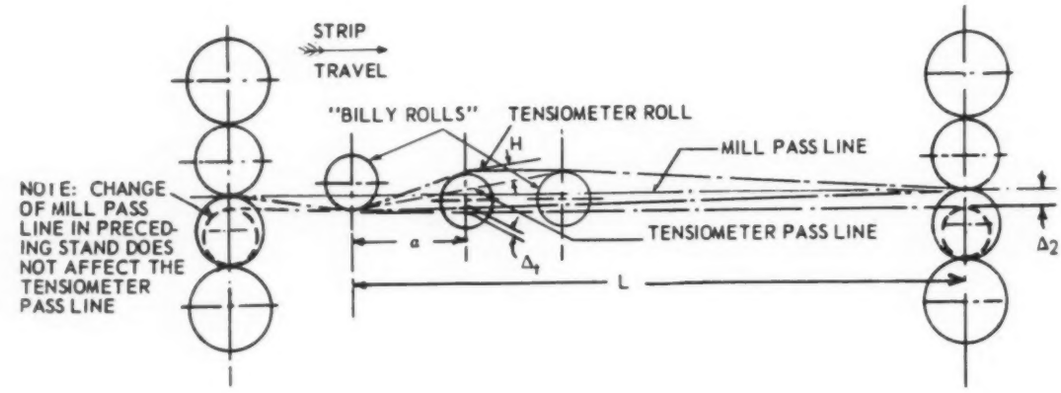


Figure 13 — The installation of two billy rolls establishes a constant pass line over the tensiometer roll and eliminates the need for elevation adjustment.

sary to correctly adjust the tensiometer is:

$$\Delta_t = \Delta_2 \frac{a}{L}$$

Pass line variations in stand No. 1 do not affect readings of the tensiometer because the angle B_1 does not change. Since stand No. 2 is far from stand No. 1, angle B_2 is very small. Therefore, failure to adjust the position of the tensiometer roll to correct for a change of position of the pass line at stand No. 2 does not introduce a large error in the reading.

If the pass-line variations in stand No. 2 are limited, height adjusting may be omitted providing that errors of less than eight per cent can be tolerated.

If the tensiometer roll is positioned between two billy rolls, as shown in Figure 13, the tensiometer reading does not change.

SUMMARY

Since 1950, small-travel tensiometers have been used for most applications, for indicating and regulating tensiometers.

All tensiometers in a tandem mill are interchangeable and one spare can be used in any location.

To take care of tension differences between stands, tensiometers are set to different heights above the pass line. Where tension is higher, the roll is lowered, thus, the resultant force deflecting the springs is the same in all stands. Indicating meters are calibrated accordingly to tensions between stands.

Because the steel and aluminum industries are tending to automate, the trend is now toward the use of regulating tensiometers on multi-stand mills, where in the past indicating tensiometers were used.

With modern control design, it is possible to operate multi-stand mills with automatic tension regulation between stands by using regulating tensiometers. The high-power output of the latest-design magnetic transducers has contributed to the success of these installations.

Due to simplicity of design of the tensiometers, the minimum work is required to install them in the field. A large number of installations of tensiometers has been made and they have compiled a good record of reliability and performance with negligible maintenance requirements. ▲

Analytical Investigation of the Cold Rolling of Bar Stock

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....an accurate mathematical model for the cold rolling of bar stock would permit intelligent prediction of rolling load, torque and pressure distribution in the contact arc....

ONE of the purposes underlying any analytic treatment of a physical process is the development of a mathematical model from which a better understanding of the mechanics of the process may be obtained. In this way, once the validity of the mathematical model is established, the limitations and behavior of the process for any condition can be predicted with a minimum of experimentation.

This article presents a mathematical treatment of the cold rolling of bar stock between flat rolls. Although bar stock is not generally rolled in this manner this model does represent the first step in studying the problem of bars in a closed-pass mill. In addition, the problem of a bar rolled between flat rolls is the limiting case or lower bound for the rolling of strip material.

Further, since this problem of bar rolling between flat rolls has been studied experimentally in some detail by Palme and MacGregor,[1]* the mathematical model can be compared with these data. This in turn serves to establish the regions of validity of the model for this process. In this way the mechanics of the process are better understood. With this understanding as a foundation, the model can be extended to more realistic rolling situations.

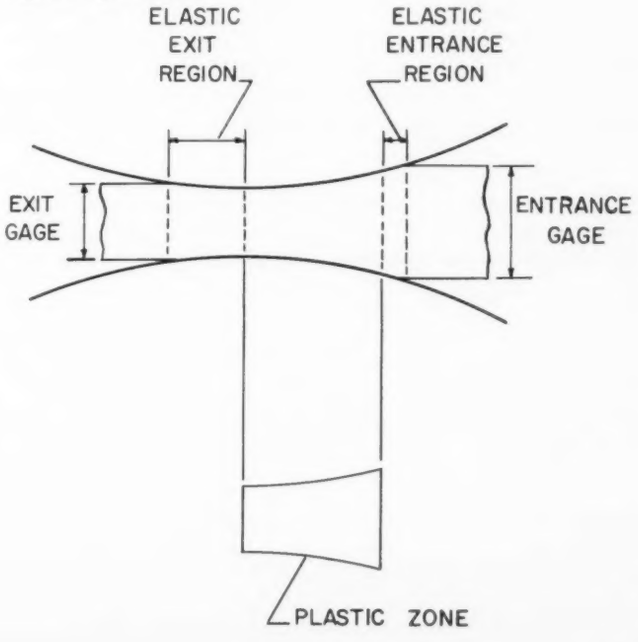
The mathematical techniques employed in this study of bar rolling represent an extension and modification of the work done by Jortner, Osterle and Zorowski[2] in the cold rolling of strip material.

Jortner's work considered the deformation of the work rolls, the elastic behavior of the strip within the contact arc and the local variation of the yield stress of the material in predicting rolling loads and torques for strip material. The present model for bar stock, in addition to including these considerations, also includes the effect of the elastic constraint at the entrance of the contact arc (the "peening" effect mentioned by Orowan[3]) and neglects the lateral constraint offered by wide strip.

To calculate the rolling load, torque and contact arc pressure distribution from this analytical method requires only a knowledge of the geometry of the strip and mill, the mechanical deformation properties of the material and the coefficient of friction between the material and the work rolls.

The pressure distributions, rolling loads and torques predicted by this model are compared with the experimental work of Palme and MacGregor[1] revealing the regions of validity and the limitations of the model.

Figure 1 — The strip contact arc was divided into three regions by Jortner.



* Numbers in parentheses refer to Bibliography at end of article.

ANALYTICAL MODEL DESCRIPTION

The establishment of an analytic theory of cold rolling is not a new idea. However, much of the early work in this area resorted to over-simplified models primarily because of the difficulty of obtaining solutions to the equations describing the process. As a result these solutions generally proved inadequate when applied in areas of extreme operating conditions.

The recent work of Jortner[2] has eliminated many of the over-simplifications present in the earlier work on cold strip rolling by considering the behavior of the strip locally as it passes between the work rolls. His model considers the strip contact arc between the rolls divided into three regions: an elastic entrance region, a plastic region and an elastic exit region, see Figure 1. The boundaries between these regions are treated as planes assuming that all of the strip material passes from the elastic to plastic states at the same time.

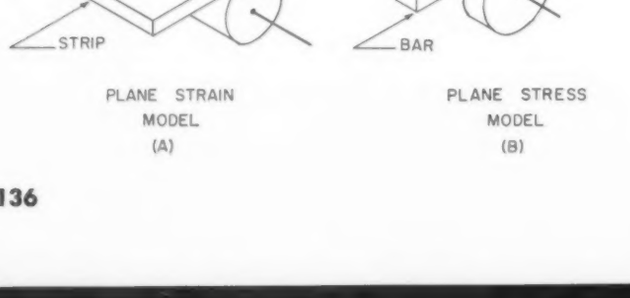
Since the behavior of the strip is considered locally, the variation of the yield stress of the material through the arc of contact is included. In addition Jortner was able to account for the work roll deformation more accurately and at the same time to make the strip shape within the contact arc compatible with the flattened roll shape.

In this model the state of deformation within the strip is treated as 2-dimensional by assuming that there is no lateral spread of the strip. This corresponds to a state of plane strain and is generally accepted as a reasonable model for the deformation of wide strip.

However, this state of deformation is not applicable to the rolling of bar stock. As the strip becomes narrow approaching bar stock, the lateral restraint offered by its width diminishes and lateral deformations will occur. In the limit as the width of the material becomes smaller than the thickness, the stress across the width (in the lateral direction) approaches zero, resulting in a 2-dimensional state of stress. This state of plane stress provides the basis for a 2-dimensional analytical model of bar stock rolled between flat rolls. Because this treatment does not include the effect of any lateral restraint offered by the work rolls on the material, the rolling loads and torques predicted by this analysis should be a lower bound to the actual values.

In Jortner's analysis of wide strip, the work roll deformation was derived by assuming that a state of plane strain existed in the rolls as well as the strip. This corresponds to neglecting edge effects in both the strip and the roll, see Figure 2A. As the strip becomes narrow, approaching bar stock, the state of deformation in the work roll will become 3-dimensional since due to the reduced width of the loading the state of plane deformation is no longer valid. However, a limiting condition for roll deformation is obtained by assuming that a state of plane stress also exists in the work roll.

Figure 2 — Modification of the strip model from plane strain to plane stress is done by re-deriving the equations assuming the lateral stress to be zero.



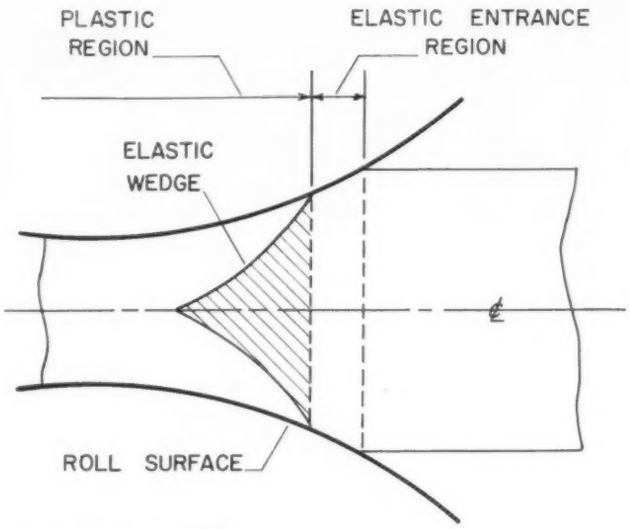


Figure 3 — The analytical model assumes an elastic wedge extending into the plastic zone of deformation.

The use of states of plane stress in both the work rolls and the bar material in this analysis corresponds physically to rolling of bars between disk rolls, see Figure 2B. This analytical model is mathematically consistent and should provide a lower limit for the values of rolling load and torque.

The modifications of the strip model from plane strain to plane stress in the elastic entrance and exit regions of the strip are accomplished by re-deriving the elastic strip equations considering the stress in the lateral direction (across the width of the material) to be zero. In the same manner the elastic roll deformations are also re-derived.

In the plastic region the assumption of homogeneous compression is retained in the bar stock model. However, the assumption of a state of plane stress affects the yield criterion for the plastic behavior of the material. Modification of the yield criterion requires imposing the restrictions of plane stress on the Von Mises-Hencke yield theory which is used as the basis for the plastic analysis.

In the rolling of thin strip the roll radius to strip height ratio (R/h) is generally quite large. This results in a strip height to contact arc ratio (h/L) less than unity. For these conditions the assumption of plane boundaries between the elastic and plastic regions is quite reasonable.

However, in the cold rolling of bar stock the R/h ratio will in general be smaller than for strip and the ratio of bar thickness to contact arc may approach and become greater than unity. Under these conditions the elastic-plastic boundary can no longer be considered a vertical plane. Instead an elastic wedge will extend into the plastic region as illustrated in Figure 3. The effect of the elastic wedge is to add additional constraint to the material being rolled causing the contact pressures to rise in the vicinity of the wedge. This elastic

constraint is referred to as the peening effect.[3]

When the ratio of bar thickness to contact arc approaches or exceeds unity, this effect should be included in the mathematical model. It has been incorporated in the present bar stock analytical model using the method suggested by MacGregor and Palme.[4]

Experimental evidence[1] indicates that this peening effect is more predominant in the entrance region of the bar contact arc than near the exit region. For this reason the analytical model only incorporates this effect in the entrance region. The elastic-plastic boundary near the bar exit is treated as a plane boundary as in the wide strip model.

The analytical model for the cold rolling of bar stock between flat rolls is based upon the following considerations:

1. An elastic entrance and exit region.
2. Elastic roll deformations compatible with the deformed bar shape.
3. The variation of yield stress of the rolled material along the contact arc.
4. A plane state of stress in the work rolls and elastic regions of the material being rolled.
5. The peening effect in the elastic entrance region.

EXPERIMENTAL RESULTS

The extensive experimental results reported by Palme and MacGregor[1] indicate the behavior of the normal pressure distributions between the rolled material and the work rolls for both bar and strip under a wide variety of conditions.

Bars of aluminum, copper and steel (1 x 1 in. in cross section) were rolled at different percentages of reduction and varying speeds. In addition, aluminum strips 11 in. wide with thicknesses ranging from 0.063 to 0.5 in. were also rolled.

The complete tests show the behavior of the normal pressure distribution as the material changes from strip to bar stock and also shows the variation of the pressure distribution of the 1 x 1-in. bar stock for different

TABLE I
Measured and Integrated Load Comparison

Palme and MacGregor Figure no.	Material and lubricant	Nominal thickness, in., and width, in.	Per cent reduction	Palme and MacGregor results				Predicted results						
				Measured torque, in.-lb	Measured load, lb	Average pressure curve load, lb	Per cent difference in loads, lb*	Coefficient of friction	Torque, in lb	Load, lb	Percentage difference in torque**	Percentage difference in load**	Mathematical model	Per cent reduction
20	Aluminum, dry	1 x 1	10.28	1,890	6,310	7,150	+13.3	0.095	1,700	6,300	− 8.6	− 3.80	Stress†	10.3
21		1 x 1	10.27	1,760	6,630	6,740	+ 1.7	0.095	1,900	7,650	+ 2.1	+16.8	Strain†	10.3
22		1 x 1	10.23	1,930	6,710	6,420	− 4.3							
23	Aluminum, dry	1 x 1	9.63	1,780	5,350	6,670	+24.9	0.095	1,530	5,640	− 3.8	− 9.2	Stress†	8.7
24		1 x 1	7.32	1,500	4,750	6,030	+27.0	0.095	1,750	6,950	+10.0	+11.9	Strain†	8.9
25		1 x 1	8.65	1,590	6,210	5,820	− 6.3							
26	Aluminum, dry	1 x 1	20.54	3,960	9,800	10,200	+ 4.1	0.095	2,700	9,670	−38.0	+ 1.0	Stress†	20.8
27		1 x 1	20.31	3,720	9,350	10,500	+12.3	0.095	3,250	11,200	−12.7	+16.0	Strain†	20.8
28		1 x 1	20.21	3,490	9,830	10,760	+ 9.5							
32	Aluminum, palm oil	1 x 1	5.9	1,110	4,070	5,350	+31.4	0.067	940	4,890	−17.5	+18.5	Stress†	6.1
33		1 x 1	5.92	1,170	4,180	5,970	+40.5	0.067	1,100	5,500	− 3.5	+33.4	Strain†	6.1
36	Aluminum, dry	0.5 x 1	20.38	1,880	7,020	9,650	+37.5	0.095	1,770	6,700	− 5.8	− 4.6	Stress†	20.4
								0.095	1,820	7,480	− 3.2	+ 6.5	Strain†	20.4
37	Aluminum, dry	0.25 x 1	30.68	2,010	9,230	12,030	+30.5	0.095	1,530	7,240	−24.0	−21.5	Strain	30.7
								0.15	1,750	8,050	−13.0	−12.8	Strain	30.7
38	Aluminum, dry	0.125 x 1	50.0	2,450	13,020	16,850	+29.5	0.095	1,900	10,350	−22.4	−20.5	Strain	50.2
								0.15	2,300	13,000	− 6.1	− 0.15	Strain	50.2
39	Aluminum, dry	0.0625 x 1	48.1	1,320	9,370	13,336	+42.5	0.095	950	7,325	−28.0	−21.8	Strain	48.4
								0.15	1,300	9,700	− 1.54	+ 3.5	Strain	48.4
52	Steel, dry	1 x 1	4.83	4,550	25,000	34,840	+39.3	0.085	4,800	24,000	− 6.8	− 6.9	Stress†	5.02
53		1 x 1	4.74	5,440	25,940	34,810	+34.2	0.085	6,000	27,600	+16.4	+ 7.0	Strain†	5.05
54		1 x 1	4.85	5,470	26,440	35,040	+32.6							
55	Steel, dry	1 x 1	10.17	10,740	39,420	50,360	+27.7	0.085	9,000	38,400	−16.4	− 1.6	Stress†	10.4
56		1 x 1	10.16	10,870	38,630	47,290	+22.4	0.085	10,500	43,400	− 2.5	+11.2	Strain†	10.4
57		1 x 1	10.06	10,690	39,000	48,870	+25.3							
59	Steel, dry	1 x 1	15.4	16,880	50,150	57,680	+15	0.085	11,800	47,800	−28.4	− 5.9	Stress†	15.7
60		1 x 1	15.4	16,330	51,490	55,670	+ 8.1	0.085	12,000	54,000	−27.2	+ 6.3	Strain†	15.8
61		1 x 1	16.16	16,240	50,730	62,300	+22.8							
62	Steel, palm oil	1 x 1	4.89	5,370	25,480	33,820	+32.7	0.060	4,000	23,800	−22.9	− 7.5	Stress†	5.0
63		1 x 1	4.82	5,010	25,990	38,800	+49.6	0.060	4,800	27,000	− 7.5	+ 4.9	Strain†	5.2

* Based on measured load. ** Based on Palme and MacGregor averaged measured load. † Peening effect included in analysis.

materials and varying percentage reductions.

In addition their report also presents the stress-strain characteristics of all of the materials tested, together with the rolling load and torque measured directly from the rolling operation.

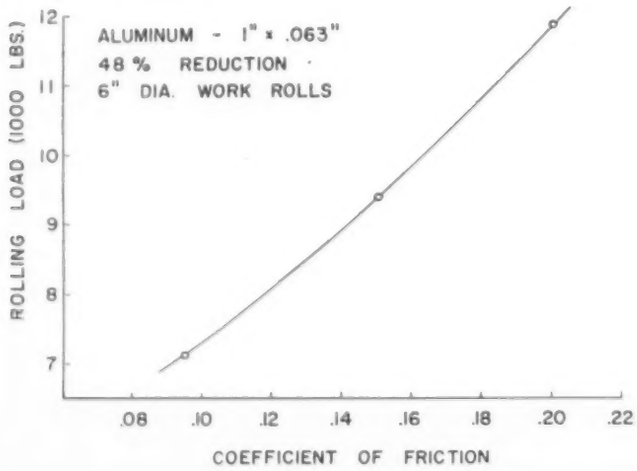
To establish the consistency of the results presented by Palme and MacGregor, their measured values of the rolling loads were compared with the loads determined from the area under the normal pressure curves. In almost all cases there was considerable difference between the measured and integrated loads. The results of this comparison are shown in Table I. The average pressure curve load referred to in this table is the value of the load obtained from the average of all of the pressure curves presented for any one pass. These different pressure curves, for a given pass, were obtained at different lateral positions on the bar as it was being rolled.

As would be expected, the normal pressures change with the lateral location of the sensing pin, the pressures becoming smaller as the edge of the bar is approached. In order to obtain the true value of the rolling load from the pressure distribution, the average lateral pressure at each point along the contact arc must be known. The Palme and MacGregor report does not present sufficient results to establish the average lateral pressures. However, it is evident that had these data on the lateral behavior of the pressure been available that there would have been closer agreement between the measured and the integrated results.

In order to measure the local pressures between the strip and the roll, Palme and MacGregor used a sensing pin embedded in the roll and projecting slightly beyond the roll surface. The diameter of the pin (0.1045 in.) was equivalent to two degrees of arc length along the roll surface. In their investigation the arc of contact for the bars and strips varied from approximately 6 to 18 degrees.

It is apparent that the recorded pressure distributions do not really represent the local behavior along the arc of contact but are really an average over the two degrees of pin contact arc. For the smallest contact arcs, this represents averaging the pressure over 30 per cent of the contact arc. At best the pin is averaging the pressure over about 11 per cent of the contact arc for the 18-degree case.

Figure 4 — The predicted total load varies with the value of the coefficient of friction.



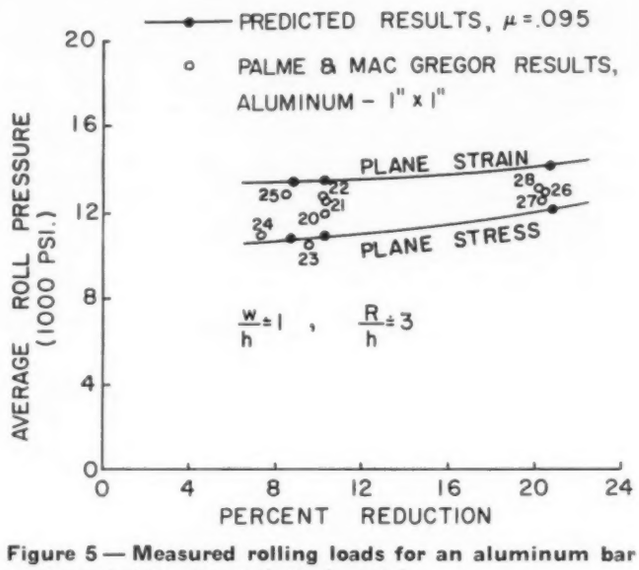


Figure 5 — Measured rolling loads for an aluminum bar are bounded by the analytical models.

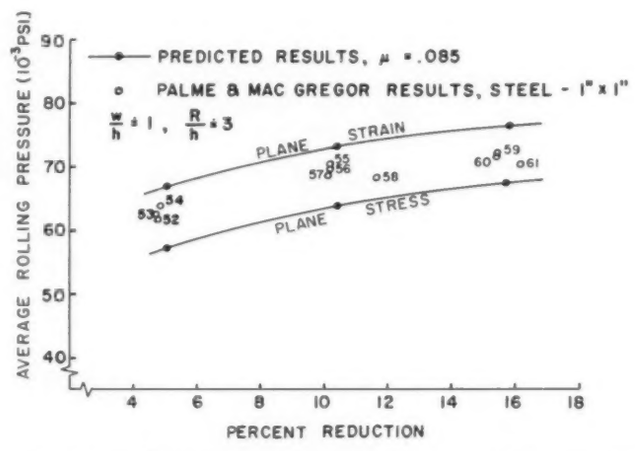


Figure 6 — Measured rolling loads for a steel bar are bounded by the analytical models.

However, even though some question does exist as to the actual local pressure variation obtained by the investigators, it is believed that the recorded pressures do give a qualitative representation of the shape of the pressure distribution.

ANALYTICAL RESULTS

In order to predict the pressure distributions, rolling loads and torques from the analytical model it was necessary to establish the values of the coefficients of friction for the various materials, in addition to knowing the yield stress characteristics of the material and the rolling geometry. Since Palme and MacGregor did not determine the coefficients of friction, the work of Whitton and Ford[5] was used to establish this information.

Whitton and Ford have suggested the following values for the coefficients of friction:

Aluminum (no lubrication) ..... $\mu = 0.095$
Aluminum (palm oil) ..... $\mu = 0.067$
Steel (no lubrication) ..... $\mu = 0.085$
Steel (palm oil) ..... $\mu = 0.060$

Using the yield stress characteristics reported by Palme and MacGregor[1] and the coefficients of friction

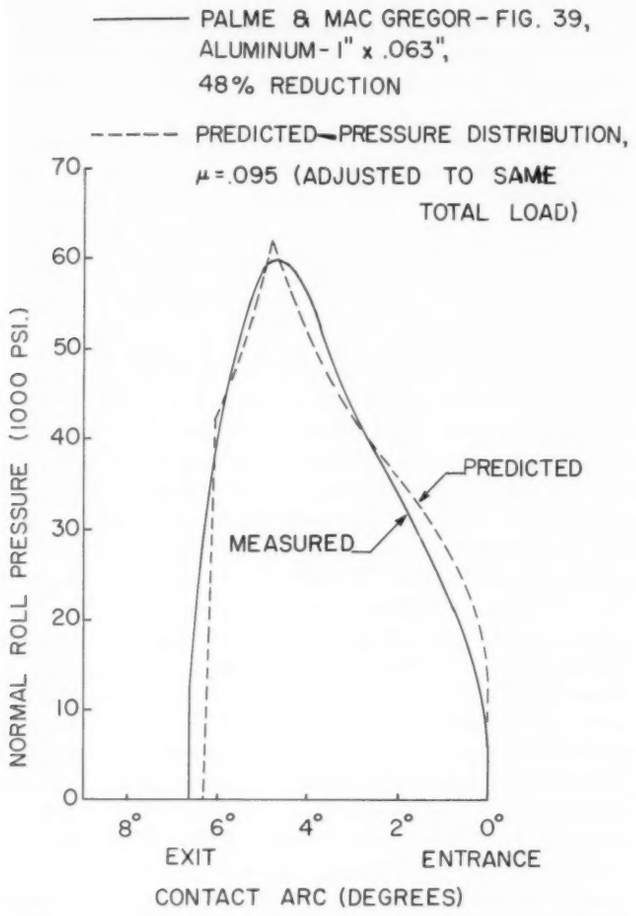
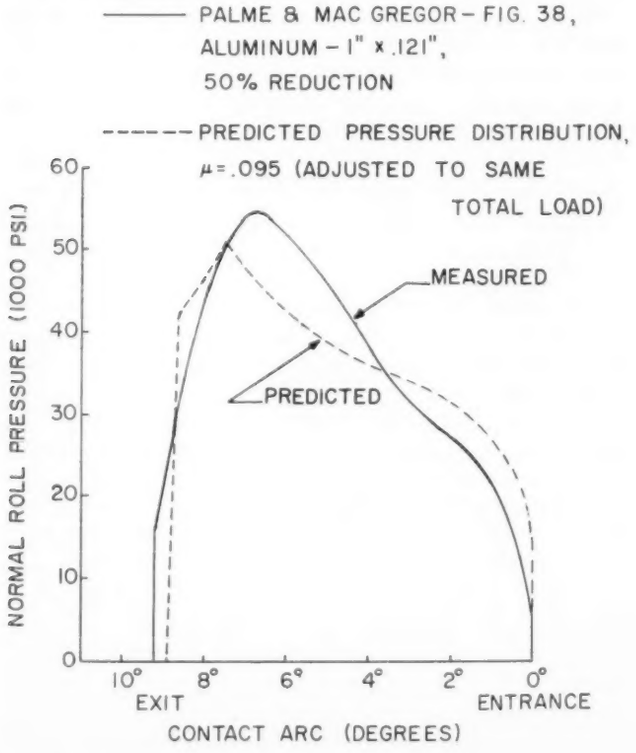


Figure 7 — Recorded and measured roll pressures for a bar with width to thickness ratio of 16 to 1 show the friction-hill distribution.

Figure 8 — Decreasing the bar width to thickness ratio of eight to one instigates the formation of a pressure hump at the entrance region.



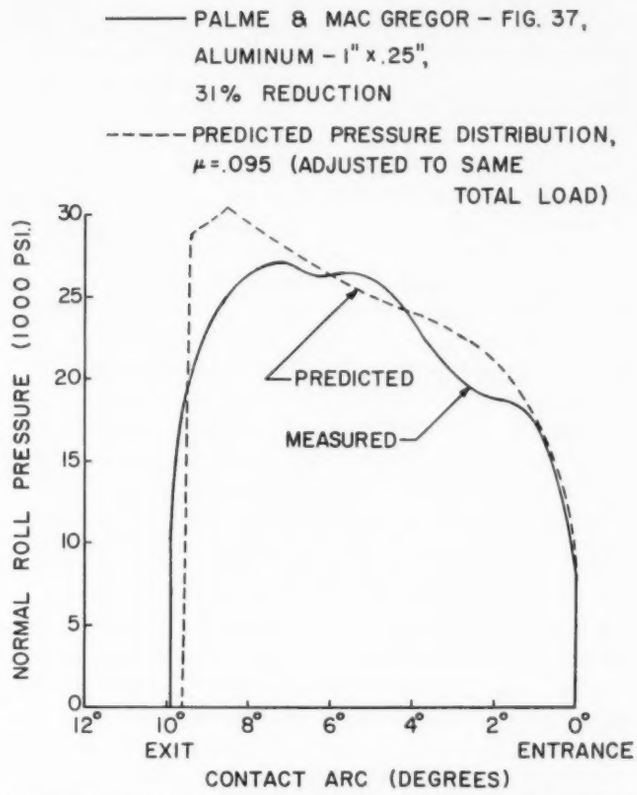
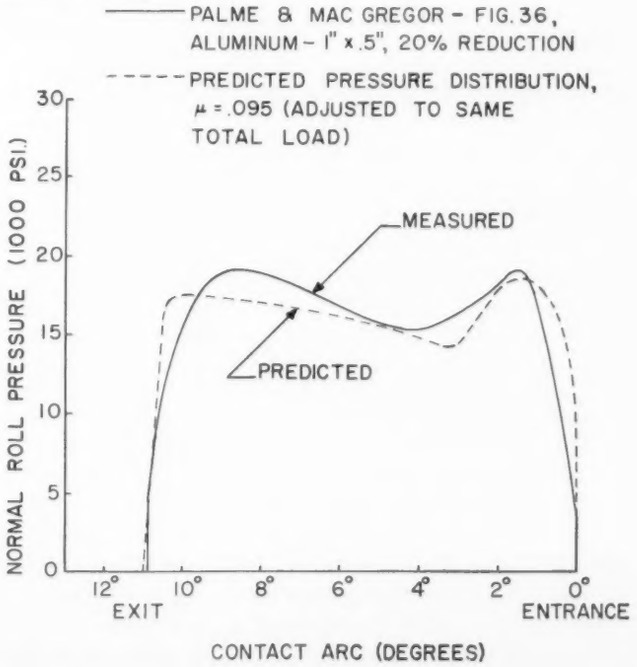


Figure 9 — If the bar width to thickness ratio is decreased to four to one, the entry pressure peak becomes a more easily recognized area.

of Whitton and Ford,[5] the analytical equations were solved on a computer for the normal pressure distributions, rolling loads and torques. The results of these calculations are reported in Table I.

Since the plane-stress model for the rolling of bar stock was intended to provide a lower bound on rolling

Figure 10 — With a bar width to thickness ratio of two to one, the entry pressure peak becomes greater than the friction-hill peak.



loads and torques, the equations were re-solved using the plane-strain strip model to provide an upper bound on these same values. The actual loads and torques should in general lie between these two bounds.

Because of the inconsistency between the loads measured by Palme and MacGregor and those obtained from the area underneath their pressure curves, there was some question as to which loads to choose for comparison with the predicted results. However, since the pressure curve loads were felt to be higher than the actual loads due to the variation of pressure laterally across the width of the strip, the measured loads were selected for comparison with the predicted results.

In Table I, No. 20 to 33 and 52 to 63 give the results for the 1 x 1-in. aluminum and steel bars. In general the predicted loads do bound the average load measured by Palme and MacGregor. The predicted torques are somewhat more erratic in their behavior and tend to be lower than the measured values. In Table I, under the column headed "Mathematical model," the type of analytical model that was used is indicated. The letter (P) following either stress or strain means that the peening effect was included in the plane stress or plane strain analysis.

The strip tests, No. 36 through 39 in Table I, show that the predicted results are consistently low for a coefficient of friction of 0.095. In an attempt to establish the effect of the magnitude of the coefficient of friction on the predicted rolling load and torque, test No. 39 was re-analyzed for coefficients of friction varying between 0.095 and 0.2 without taking into account the deformation of the work roll.

Figure 4 shows the variation of the predicted total load with coefficient of friction. These values are lower than those reported in Table I because the effect of roll deformation, which increases the total load, has not been included in the results shown in Figure 4.

On the basis of Figure 4 a value of 0.15 was chosen for the coefficient of friction in order to improve the prediction of the rolling loads and torques for the strip cases. The results in Table I for the strip tests (36 to 39) show considerably better agreement when this value of the coefficient of friction is used. There is no apparent reason for suspecting that the coefficient of friction would change for these strip tests. However, it is to be noted, that MacGregor and Palme[4] used a coefficient of friction of 0.17 in their attempt to predict the measured load.

Test No. 36, in which the piece was 0.5 x 1 in., can neither be considered as strip or bar. It was analyzed both with the plane stress and plane-strain models with the peening effect included. It is observed that again these analyses bound the measured results for the total load in dictating that the width to thickness ratio is not large enough for the piece to be considered as strip.

In general the measured rolling loads for 1 x 1-in. bars are quite well bounded by the limiting analytical models of plane strain and plane stress. This is shown in Figures 5 and 6 where the average rolling pressure over the contact arc is plotted against per cent reduction for both the measured and predicted results.

Even though a mathematical model may predict the rolling load and torque within the limits of engineering accuracy, this does not necessarily imply that the model accurately describes the behavior of the normal pressure distribution within the contact arc. If a mathematical model is to lead to a better understanding of the rolling process, it must predict the local behavior of the pressures within the contact arc as well as predict the rolling load.

Since the predicted total load is obtained from a calculated pressure distribution, these pressure distributions will necessarily be of smaller magnitude than those recorded by Palme and MacGregor. This can be observed in Table I where the average pressure curve load is shown to be consistently greater than the measured load.

It was mentioned earlier that the pressure curves recorded by Palme and MacGregor are probably qualitatively correct. Thus in order to make a qualitative comparison between the shapes of the recorded and predicted pressure distributions, the predicted pressure distributions were adjusted to give the same total load as that found from the area under the recorded pressure distribution.

Figures 7, 8, 9 and 10 show this qualitative comparison between the recorded and predicted pressure distributions for the tests which illustrate the effect of decreasing the thickness to width ratio. Figure 7 shows the typical friction-hill pressure distribution with a single peak pressure near the exit which is characteristic of strip rolling. This is the behavior expected for this test since the material width is 16 times the thickness and can be considered strip.

As the thickness of the material increases for the 1-in. wide stock, the pressure curves begin to develop a secondary hump near the entrance region. This effect is observed in Figures 8 and 9, and in Figure 10 the secondary hump has become as dominant as the friction-hill peak.

As indicated in Table I, the predicted curves in Figures 7, 8 and 9 were calculated from the plane-strain model without peening. In Figure 10 the plane-stress curve with the peening effect included is shown. The introduction of the peening effect in the mathematical model produces the peak pressure near the entrance of the contact arc. Both analytical models with peening included were used for this test since the width was only twice the thickness and the contact arc was nearly equal to the thickness. Except for slightly larger values for the pressures, the shape of the distribution obtained for the plane-strain model with peening is very similar to the plane-stress curve shown in Figure 10, and hence has not been included in this figure.

The predicted curves shown as dotted lines on these figures show very good qualitative agreement with the measured distributions both with respect to shape and contact arc length.

Typical pressure distributions for the 1 x 1-in. bars are shown in Figures 11, 12 and 13. Pressure distributions for 20 and 10 per cent reductions on aluminum bars are shown in Figures 11 and 12 respectively. Figure 13 presents the results for a 15 per cent reduction on 1 x 1-in. steel bar. For the measured curves the secondary hump is again dominant in Figure 11 and an exit peak can be seen, while in Figures 12 and 13 for the smaller reductions the secondary hump is also dominant but the normal exit peak is no longer apparent.

The predicted pressure distribution shown in Figure

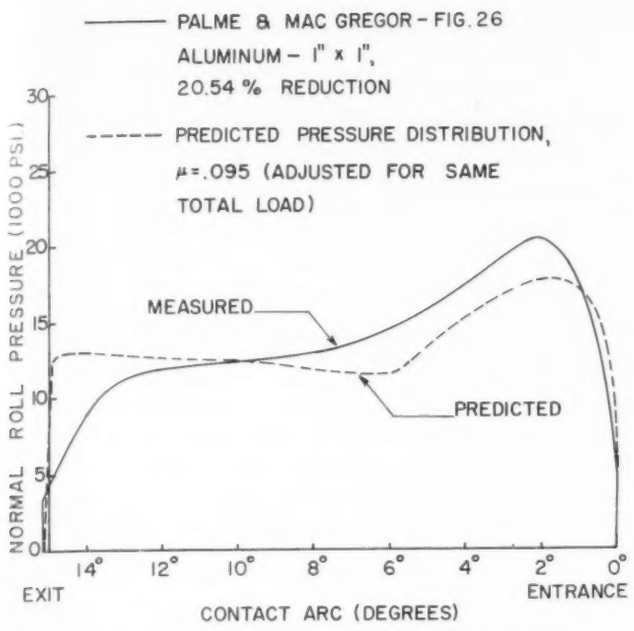


Figure 11 — The predicted pressure distribution was calculated using the plane-stress model considering peening.

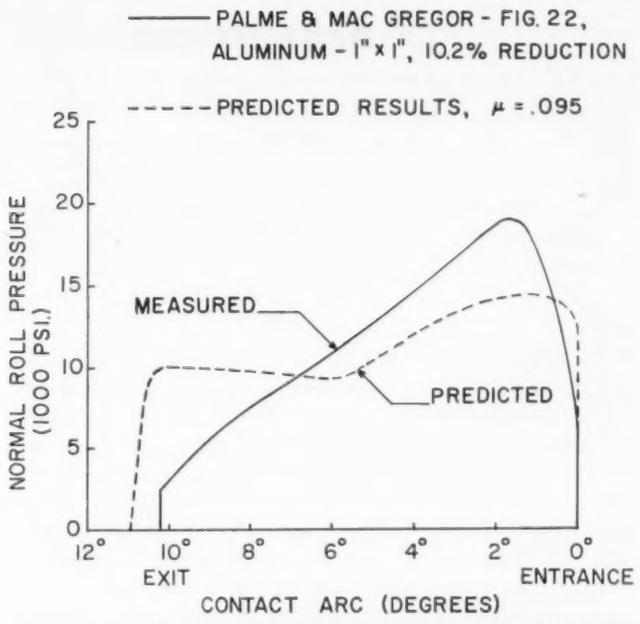


Figure 12 — The predicted exit stress value is high because the model assumes an increase in yield stress at the pass exit during the continuing material reduction.

11 was obtained using the plane-stress model with peening. The agreement between the predicted and measured results is quite reasonable. In Figures 12 and 13 the predicted pressure peaks near the entrance (obtained from the plane-stress with peening model) compare well with the measured curves. However, the predicted curves near the exit region retain relatively high normal pressures because the analytical model assumes an increase in yield stress with the continuing reduction of material as it approaches the exit. On the basis of this qualitative comparison with the measured results, it appears that for the lighter reductions on bar stock, the present model requires modification in the vicinity of the exit region to obtain better agreement with the measured pressure curves.

Work is now underway on the modifications necessary to improve the pressure predictions near the exit regions.

SUMMARY

The analytical models using plane stress and plane strain with peening have in general been shown to provide bounds on the prediction of rolling load for bars reduced between flat rolls.

Except for light reductions on square bars (below 15 per cent), the pressure distributions predicted by the analytical models show good qualitative agreement with the experimentally measured pressure distributions.

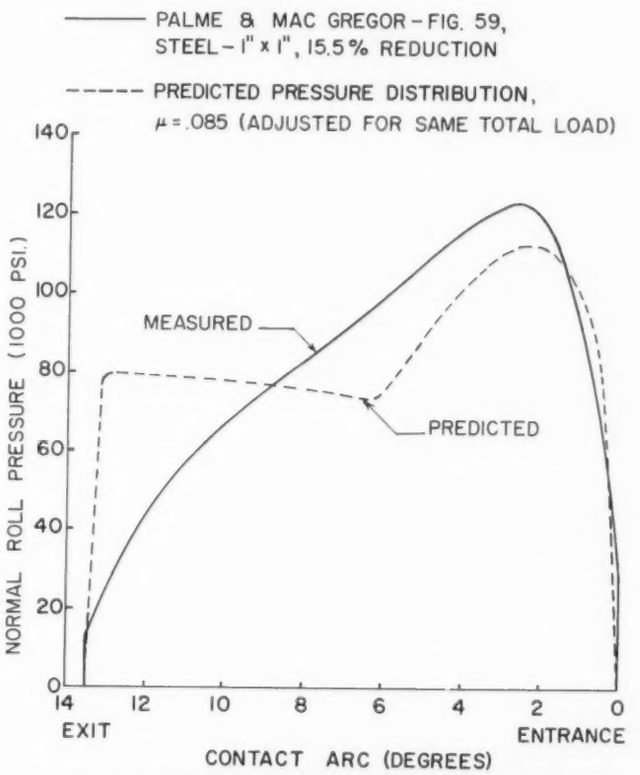


Figure 13 — For light bar stock reductions the exit region of the analytical model must be modified to present better agreement with measured data.

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Discussion

PRESENTED BY

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DR. ALVIN S. WEINSTEIN, Assistant Professor, Dept. of Mechanical Engineering, Carnegie Institute of Technology, Pittsburgh, Pa.

J. D. Keller: It is well known and has been shown by a number of different techniques that the plastic flow starts, at least to some extent, before the bar ever gets to the bite of the rolls, to the place where the surface makes contact (1) in Figure 14. That has been shown by techniques such as scribing lines on the side of the bar, or inserting copper wires and later sectioning the bar. This was also done by Dr. Sachs by taking a bar, rolling it, stopping the rolls and sectioning the piece, then treating the surface with Fry's solution, etching the surface, which shows up the lines of plastic flow. The results seem to indicate that plastic flow does begin back toward the right end of the sketch as at (2) in Figure 14, and as Sachs put it in his paper, quite a long time ago, the elastic region gradually changes to the plastic region as we go into the rolls. It is not an immediate change, but a gradual one. This action has long been known as "backward extrusion," wherein the middle of the bar is pushed backward and the surface layers are drawn forward over it by the rolls.

There is some doubt as to whether it can be correct to assume a wedge as in the authors' Figure 3, in which all the material to the right of those curved wedge lines, dotted in Figure 14 is fully elastic and the rest fully plastic. There is probably a gradual transformation from the elastic state at (3) to the plastic state further on as at (2) and finally to full plasticity as the material moves further into the space between the rolls, as at (4).

The great contribution that the authors have made in doing this should not be minimized. It is so much better than anything that has gone before, but it is not felt that from the standpoint of understanding what is going on that it is quite good enough. It will doubtless have to be modified somewhat by further experimental work.

A little bit might be said about the MacGregor and Palme tests. Those, it is understood, were originally planned for the purpose of measuring the coefficient of friction of the strip on the surface, but the experimental difficulties were so great that no results worth publishing were obtained. They did, however, get these measured pressure distribution curves. Although the paper was published in 1958, the work was actually done about ten years before. There were many discussions on the interaction of the part of the bar or strip approaching the rolls with the part already in the bite of the rolls, at about the time when Siebel's and von Karman's developments were published, and even, as regards hot rolling, years before that time. It was felt that this interaction with regard to cold rolling ought to result in an increase of pressure at and just after the strip entered the bite of the rolls, and the double-humped curves obtained in the measurements at Massachusetts

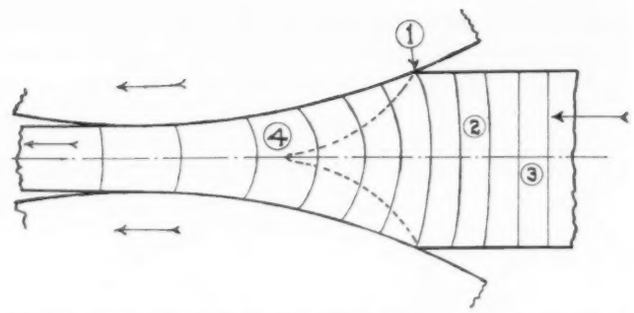


Figure 14 — Plastic flow initiating within zone 2 causes an action known as backward extrusion.

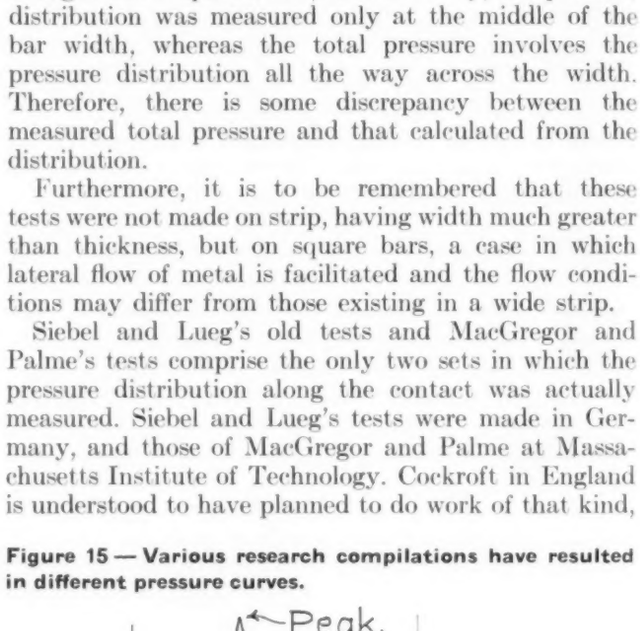
Institute of Technology seemed to verify this idea.

With regard to these tests by MacGregor and Palme, it appears that the objection that the authors have brought out is quite valid; that is to say, the pressure distribution was measured only at the middle of the bar width, whereas the total pressure involves the pressure distribution all the way across the width. Therefore, there is some discrepancy between the measured total pressure and that calculated from the distribution.

Furthermore, it is to be remembered that these tests were not made on strip, having width much greater than thickness, but on square bars, a case in which lateral flow of metal is facilitated and the flow conditions may differ from those existing in a wide strip.

Siebel and Lueg's old tests and MacGregor and Palme's tests comprise the only two sets in which the pressure distribution along the contact was actually measured. Siebel and Lueg's tests were made in Germany, and those of MacGregor and Palme at Massachusetts Institute of Technology. Cockroft in England is understood to have planned to do work of that kind,

Figure 15 — Various research compilations have resulted in different pressure curves.



but whether he has ever completed it or got along very far with it, is not known.

Siebel and Lueg measured the pressure not only at the middle of the width but across it. Analyzing those curves in conjunction with the Palme and MacGregor tests is recommended.

Some theoretical forms of the pressure curve are shown in Figure 15. You start from point (1) in Figure 15, which is the yield strength of the material before any work-hardening, and in cold rolling you end up at point (2) with the yield strength of the material after it is work-hardened to the extent that corresponds to the reduction. The rise in the pressure curve above line (1–2) is the effect of friction. This was first brought out in a paper by von Karman about 1925 in which he gave the equations for this. Siebel had already done some work on this before that, but had not worked out the equations completely, and as far as is known von Karman's work was the first accurate solution of the problem. What von Karman did was to assume that you had up to point (3) the elastic condition, then suddenly the plastic condition set in at (3), and you had a uniform pressure and flow all the way through the thickness so that a vertical plane in the strip at starting would continue to be plane right along to (4). On that basis he obtained that curve with the peak toward which the two branches rise from (1) and (2) in Figure 15. It might be said to be a sort of continental divide; on one side the flow relative to the roll surface is all toward the entrance and on the other side it is toward the exit of the strip as it passes through the length of contact.

But a little later about 1940, Koerber in Germany pointed out under most conditions you do not have that peak; you have a rounding over, or region of sticking where there is no sliding. Siebel's and von Karman's work assumed that there was sliding throughout at every point of contact where there was a slip on the roll surface. Koerber said that at some point there is going to be a region where there is no sliding, where the bar is sticking to the roll surface, although there is sliding at either side of that region of sticking. The same was pointed out a little later by Orowan, then in England.

This work has been neglected or not taken properly into account. True enough, in cold rolling it has not too great an effect. For most cold rolling the region of sticking extends over not more than ten per cent of the contact length and makes little difference in the total pressure. For hot rolling, it may be much more important.

Even with Koerber's rounded top, the theoretical or von Karman pressure distribution curve is concave upward over most of the contact length. Siebel and Lueg's tests do not show anything of the kind. In reviewing those tests, we have been unable to find any in which even a branch of the curve was concave upward. They were all humped or concave downward except where there might be a straight section toward the two ends. The only one that has been able to obtain mathematically a concave downward curve was Nadai (who has the credit of being the first to be able to integrate von Karman's equations) but he obtained results only by making a friction assumption which is felt by some to be unrealistic. The coefficient friction would have to increase linearly from zero at no speed to a maximum directly proportional to the rubbing speed; or it would be zero near the middle and maximum near the ends of contact. That is incorrect while rolling.

It is realized that the finite width of the pressure-measuring pin in the experimental tests smoothed out some of the peaks or valleys which may have existed in the actual pressure curve, but this is far from sufficient to account for the difference between the measured curve and the von Karman theoretical curve.

In spite of the excellent work done by the authors we still are not quite as certain as we might be concerning either the physical actions or the mathematics needed to calculate the pressure and the rolling loads.

A. S. Weinstein: The mathematical model used for describing the elastic-wedge effect results from combining the theoretical analysis by Hill[6] describing the increase in yield stress in the wedge region with the relationship of thickness of the elastic region to distance along the bar determined experimentally by MacGregor and Palme.[7] Thus the elastic wedge and its effect on the local yield stress is described by a combination of analytical and experimental results.

The work of Orowan[8] in examining the flow pattern of a plasticene bar has definitely shown the existence of the elastic-wedge type of behavior of the material being deformed between the rolls. The experimental evidence indicates that the surface of the material flows plastically initially, while the central regions of the material are unaffected. As the material proceeds into the roll gap, the fully plastic region extends deeper into the material, until, ultimately the entire cross section of the material is being deformed plastically.

This effect has not only been observed experimentally but a similar behavior has been shown to exist by Alexander[9] in his analysis of the slipline field in hot rolling. The work of Hill[6] from which the analytical expressions of the elastic wedge were derived has shown analytically the rise in the local yield stress in this region. Therefore, it is believed that this model, even though limited, is essentially correct.

However, Mr. Keller's point that there is no sharp line separating the elastic region from the plastic region is well taken. There is a gradual transformation between the elastic and plastic regions in the material being deformed. Further attempts are being made to obtain a better model of the transition between the elastic and plastic regions to eliminate the difficulty of having to assume a sharp line between these regions. There is no doubt that the elastic-wedge region does exist in the rolling process. It is really a question of describing the process more accurately.

In spite of the inherent limitations of the elastic-wedge model as used in this article, it does describe the essential behavior of the material in the early portion of the arc of contact. This is evident from the ability of the mathematical model to describe, qualitatively at least, the pressure profiles measured by Palme and MacGregor which represent the best experimental work that has been done thus far.

However, it is felt that in general the mathematical models do describe the essential features of the material behavior in the arc of contact and are pointing the way to a better understanding of the rolling process. ▲

A Review of Iron Ore Sintering

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. . . . in the past decade sintering has taken great strides forward in its ability to produce a uniform, easily reducible blast furnace burden . . .

THIS article, a partial review of the history and development of iron ore sintering, emphasizes the developments of the last decade, in which more progress has been made than in the forty years from 1910 to 1950. Sintering is an art, but a dynamic and changing art. Like the rest of the steel industry, it is struggling to become a science and making giant strides. Thus an examination of important recent and current developments appears to be in order, and for convenience these will be covered in four groupings: materials, process, equipment and plant.

MATERIALS

The time when the sinter plant was a dump, to which all unwanted materials were sent, has passed, along with the era of direct-shipping ore. The benefits of sinter burden in the blast furnace, such as increased production, decreased coke rate, decreased flue dust and more uniform metallurgy, are too well known to need exposition.

Within a relatively few years improved technology and the complex interaction of many factors have changed the material picture completely. The sources of supply are changing, so that the modern sinter plant is no longer required merely to agglomerate the minus ½ or ⅜-in. fines screened from direct-shipping ores, and to burn off some of the impurities. Today it must be prepared to handle a mix of several ores of different physical and chemical compositions, in varying proportions as the economic picture changes, and to produce guaranteed tonnages of uniform, quality product.

As an indication of the variations encountered, a few examples are given in Table I.

The amount of iron in the material, the form in which it occurs and the nature and amounts of impurities present, as well as the physical characteristics, all have their effects on the sintering process. Flue dust even in relatively large quantities can be incorporated very successfully, but it has a tendency to tighten the bed. Therefore, its effect in combination with the range of materials to be sintered must be carefully studied, and the mixing and conditioning properly designed to maintain bed permeability.

The increasing quantities of concentrates being used, either alone or in combination with ore fines, at first presented some problems, but modern investigative procedures have disclosed the means of handling them. For instance, adding small amounts of hydrated lime will aid in sintering most concentrates, sometimes to a marked extent, see Figure 1. However, it does not follow that all concentrates should have this additive. The gain which can be realized must be balanced against the additional cost of handling and using the lime, and the final decision based on economics.

Almost all sinter plants today have flux in the finished sinter, usually added as a combination of dolomite and limestone. The amount of flux added can vary from a portion of the furnace requirement to the full amount needed to carry the sinter burden in the furnace (self-fluxing sinter), or the sinter can even be overfluxed with the amount needed for the entire furnace charge (burden-fluxing sinter). Of course, such decisions are not made lightly. Consideration must be given to the effects, of varying the flux in the sinter, on blast furnace operation, yield and coke rate, as well as on the design and production of the sinter plant. With given materials, not only must the optimum size of the added flux be determined, but also such factors as the sinter

TABLE I

Plant	Materials	Production
Existing plants		
A	Rich ore fines	Daily average for calendar month, including all downtime equals 3.8 to 3.9 tons per sq ft. (Individual days in excess of 5.0 tons per sq ft)
B	Ore fines, concentrates and 25 per cent flue dust	Daily average equals 3.8 to 3.9 tons per sq ft. (Individual days in excess of 4.5 tons per sq ft)
C	Magnetite concentrates	Daily average equals 2.3 tons per sq ft. (However, tests have shown that, with some modifications, this plant could be rated at 3.2 tons per sq ft, with a capability of 3.7)
Proposed plants		
D	Ore fines, concentrates, mill scale and 10 per cent flue dust	Rated at 3.0 tons per sq ft, capability of 3.5
E	Ore fines, concentrates and 10 per cent flue dust	Rated at 3.3 tons per sq ft, capability of 3.9

quality and production, the mix conditioning, the sinter screening, cooling, handling and storage, all of which may be affected by varying amounts of flux. Only after the over-all economic picture is developed can the logical decision be made, and it may well be that because of anticipated changes the correct decision today will not be correct two years from now. This naturally requires that the design of plant and process be sufficiently flexible to accommodate all anticipated changes and even, within reason, unanticipated but possible changes. Where competent design can furnish such flexibility at little or no cost, it should be required. On the other hand, if the cost of full flexibility is significant, it also must be integrated into the economic picture, and possibly a compromise made.

Fortunately, there are today so many modern operating plants and such a wealth of laboratory test data which can be correlated with actual plant performance, that it is possible to predict with high accuracy the performance of a proposed plant from laboratory test data.

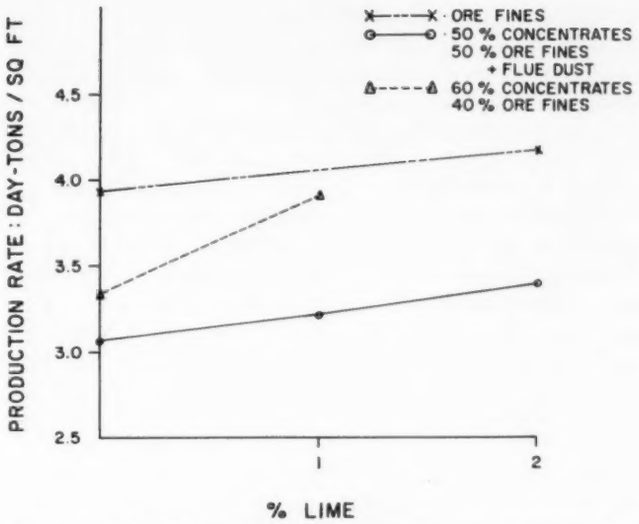


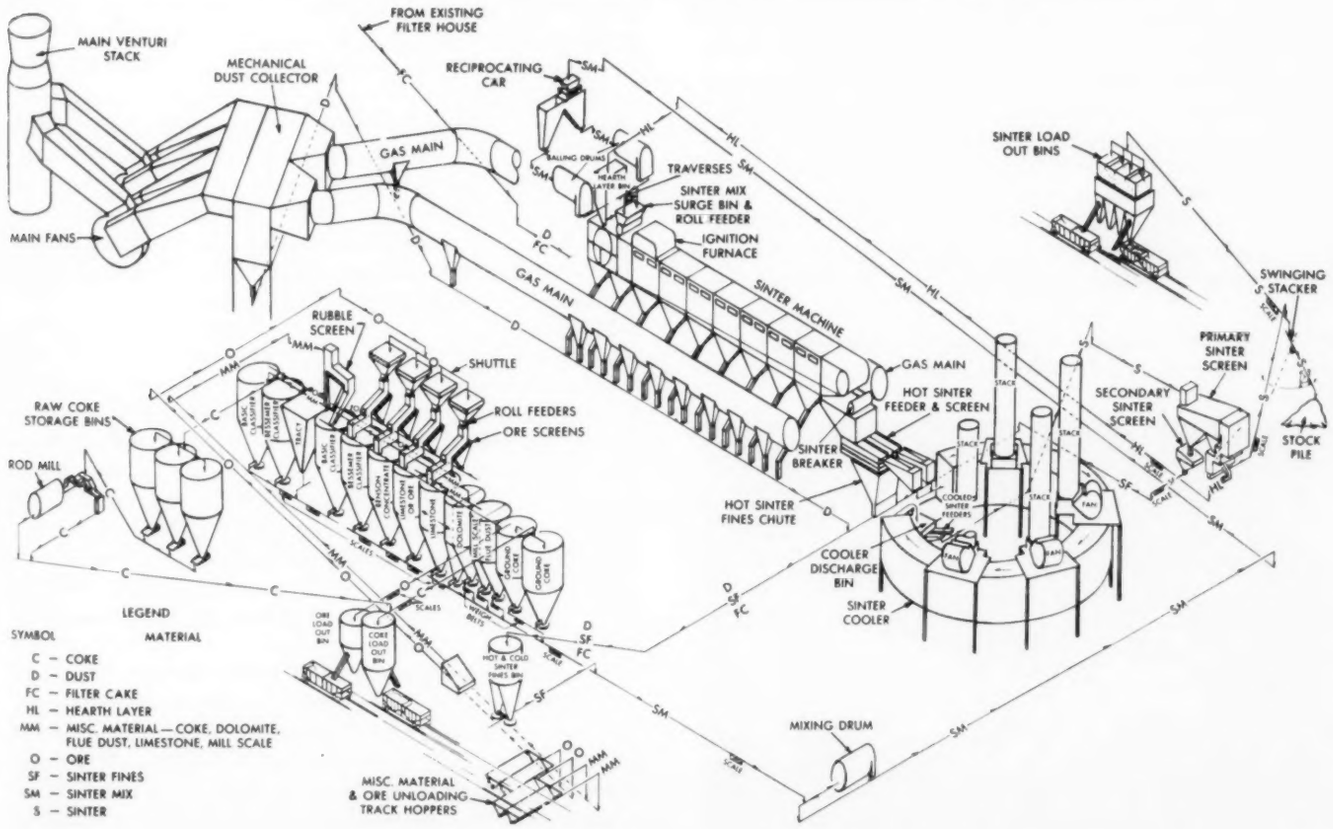
Figure 1 — Addition of lime can produce an increase in sinter production.

PROCESS

In addition to sintering, there is considerable current interest in pelletizing and briquetting. Each process has its advantages and drawbacks, and each has, or will have, its proper place. Like the man reading his obituary in the newspaper, any reports on the demise of sintering appear to be somewhat premature. The many published results, with both normal and self-fluxing sinter, in larger yields from the furnaces and lower coke rates; the reliable operation of sintering equipment as demonstrated over years of service; the controlled quality and economies possible today; the ability of the sintering process within its limits of application, to use materials as furnished from screening or concentrating operations without regrinding; all make it certain that sintering will be with us for some time to come.

The process (Figure 2) may be said to start with the proportioning of the raw materials in the amounts required, thus furnishing the proper ingredients of the mix. In the old plants this was a fairly simple, but not too accurate, process. Today, however, a great deal of attention is given to this phase. The necessity of using a number of ores, concentrates, additives, fluxes and fuel, in varying proportions and with the accuracy needed to

Figure 2 — Flow chart illustrates the raw material and product flow throughout the sintering operation.



meet and maintain prescribed standards of quantity and quality, requires equipment of great reliability and high accuracy. Such equipment is available today and will be described later in the article.

Another consideration for a modern plant is automation. Assuming a rate of $3.50 an hr, the annual direct cost of a single operator is about four times $7300, or roughly $30,000. Thus the elimination of one operator should be worth an investment of $60,000, and if two or three can be saved by automating certain functions a fairly substantial investment in the automation can be justified. The availability of equipment to furnish uniform feeds at precisely controlled rates now makes a considerable degree of automation feasible, certainly to the point of saving labor. Because of the fact that variations in the materials, some of which may be quite minor and some of which are not in current practice measurable on a continuous basis, may cause disproportionate variations in quantity or quality, a fully automated plant is not presently feasible.

Of course, an automated plant will include much more than the materials proportioning system. The central computer must also control conveyor speeds, the amount of recirculated fines, the mixing and conditioning system, the machine and cooler speeds, the burn-through point, the bed depth and the fans. It must run continuous analyses on all materials and the product. Actually, controls and devices for all of these functions are available today, but some of them are still too costly, complicated and delicate. The continuous integration, adjustment and compensation of all factors (Figure 3) to maintain quantity and quality of production appears, at the moment, to be best handled by the intuitive response of a top-grade, experienced operator. This is why sintering is still an art.

Nevertheless, in order for the operator to use his skill to best advantage, those considerable portions of the process which can well be handled automatically should be so arranged. As indicated before, this can be made to pay for itself in labor savings. Good design will dictate that the entire system of equipment-controls-instrumentation be so planned that additional functions, up to the ultimate, can be incorporated into the automatic system as justified.

With the raw materials, additives and fuel correctly proportioned, the next step in the process is to combine these ingredients into a homogeneous mix, and to condition this mix and place it on the sintering machine in such a way as to preserve its homogeneity and ensure the maximum possible permeability. The homogeneity is necessary for uniform quality, and the high permeability as well because, for a given material and bed depth (and uniform fuel distribution), production rate is primarily dependent on fuel quantity and sizing and air flow.

Figure 3 — The operator must respond properly to instrumentation stimuli to maintain production quality and quantity.

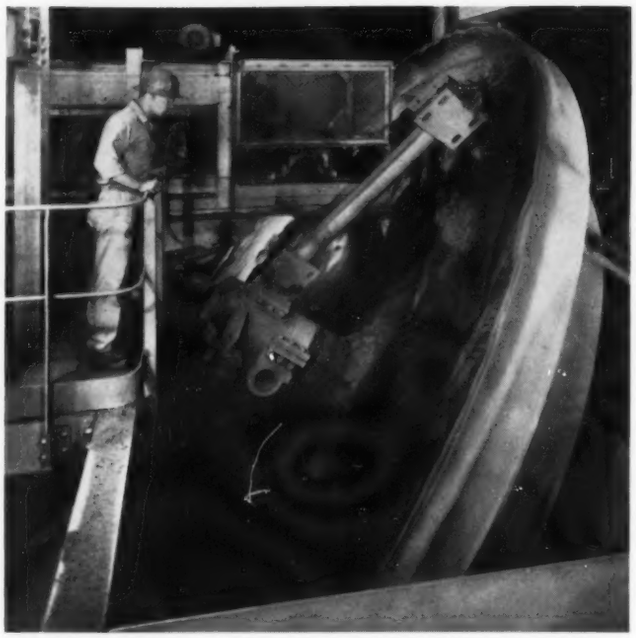


Figure 4 — Raw materials are thoroughly mixed to produce a porous texture sinter mix.

The large variety of materials being sintered today makes it impossible to say that any one mixing system is best for all applications. The materials must be thoroughly mixed, and the mix so conditioned that a fluffy, porous texture is attained while preserving sufficient structural strength to withstand packing on the bed, under the influences of gravity and suction. One and two-stage mixing are both in common use. Some materials can be mixed and given the desired texture in a single stage, while others benefit by a second stage in which additional mixing, partial balling and agglomeration of fines into micro-pellets can occur. Some materials are fairly insensitive to the method of mixing, while others show very marked differences in production. This can only be determined by tests with the given materials.

In older plants the single or first stage was usually a pug mill. However, it is seldom necessary today to use a pug mill and most people prefer to avoid this item where practical, because of the high cost of maintenance. Therefore, the trend today is to use a mixing disk or drum (Figure 4) for the first or single stage, and a drum for the second stage where required. In some cases the effect of two-stage mixing can be achieved in a single drum, which then has lifter blades in the first third of its length.

Some percentage of return fines in the mix is always desirable, to improve the structure and permeability of the bed, but it has been found that the position in the process flow where these are added is sometimes important. There are a number of ores and combinations which show definite production benefits by adding re-

turns after mixing, rather than before. If little or nothing is to be gained it is simpler and, therefore preferred to add them before mixing. However, when results justify it, returns should be added after mixing. When this is done, there is a little extra complication in proportioning, and possibly (depending on layout) some additional dust control may be required. Also, even with the hot fines laid on top of the mix, at the first transfer point the materials are so mingled that some of the hot particles get to the bottom of the burden on the following belt, with consequent shortening of belt life. Special precautions must be taken to avoid this condition.

The size of the return fines has also been thoroughly investigated in the last few years. Not many years ago, blast furnace operators believed that the furnace charge should contain no material below $\frac{3}{8}$ in. and since it was also thought that material up to this size in return fines benefited the sinter mix, $\frac{3}{8}$ in. became the natural separation point in sinter screening, between product and return fines. However, fairly recently two things have operated to change that picture: first, the furnace operators will not accept sizes down to $\frac{1}{8}$ in.; and second, tests on sinter production with varying sizes of returns show no practical effect within this range. Therefore, since the breaking of the sinter cake almost always produces sufficient fines for process purposes, it is clear that the screen separation between product and returns should be as low in size as is feasible, see Figure 5. For a large-tonnage operation, particularly with hot material, the practical limit appears at present to be about No. 4 mesh ($\frac{3}{16}$ in.). This means that all of the machine production between $\frac{3}{8}$ and $\frac{3}{16}$ in., formerly recirculated, is now available as useful product.

The continuing search for ways to increase production with lower cost and less maintenance has also led us to examine the grate bars on the sinter machine pallets, as well as the pallets. As with the other subjects touched on in this article, a very respectable treatise could be written on the research and development which has gone into these, including the metallurgy of the materials. It is sufficient to say here that, apart from their metallurgy, the shape and size of grate bars are important. A wide, heavy bar has a high heat capacity and therefore, with proper design, can have a long life. A thin, light bar for the same application has much smaller heat capacity and a correspondingly shorter life. On the other hand, it has been found that changing from $1\frac{1}{4}$ to $\frac{1}{2}$-in. grate bars increased production an average of 8 per cent, because of the greater open area for gas flow. Thus another economic study is required, the value of the increased production being balanced against the cost of the shorter grate bar life.

However, there are ways of weighting the balance in the desired direction. For instance use of a hearth layer permits the use of a wider grate bar. It is true that some additional cost is involved in conveying the hearth layer, providing a surge bin, feeding it onto the grate bars and furnishing a little extra height of sidewall. There is virtually no cost for screening the hearth layer, since this can be accomplished along with the necesssary separation of product and fines. Once made, the hearth layer is simply recirculated, with only a slight makeup to cover the size degradation, the excess hearth layer

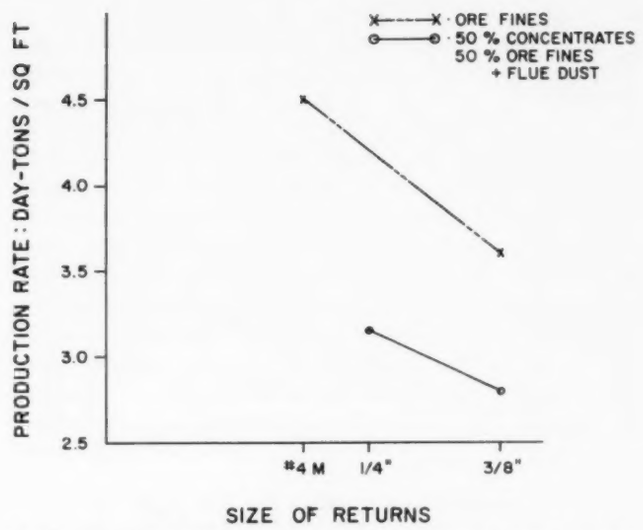


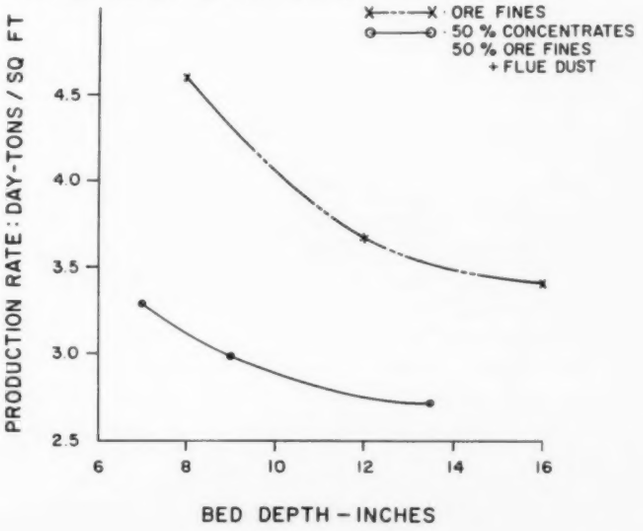
Figure 5 — Reduction of the size of return fines to the lowest permissible size allows use of a large percentage of product.

screened out being diverted to the product belt. Thus the use of the hearth layer causes no significant decrease in production per se. On the other hand, it avoids a decrease (or permits an increase) as explained above.

There are other advantages in using a hearth layer, such as lower grate bar temperatures, less fine material drawn into wind boxes and gas main, easy separation of the sinter cake at the discharge end, and virtual elimination of "stickers" on the return strand. For these reasons a hearth layer is almost always used today.

Another fruitful field of investigation has been the bed depth on the machine. There are obviously a number of other variables affected by this one, so here again it is difficult to generalize. Operating plants are running with bed depths all the way from 6 to 18 in., and probably all of them have some reason to believe (from plant trials or otherwise) that the depth they are using is optimum for their conditions. Undoubtedly this is true in a number of cases, but there are a number of others where it is not. Lest this seem to be an indictment of plant operators, it is only fair to point out that most older plants (and some modern ones) do not have suffi-

Figure 6 — Bed depth can be an important factor in determining the rate of sinter production.



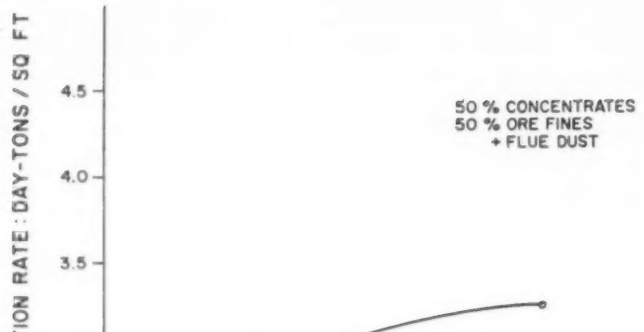


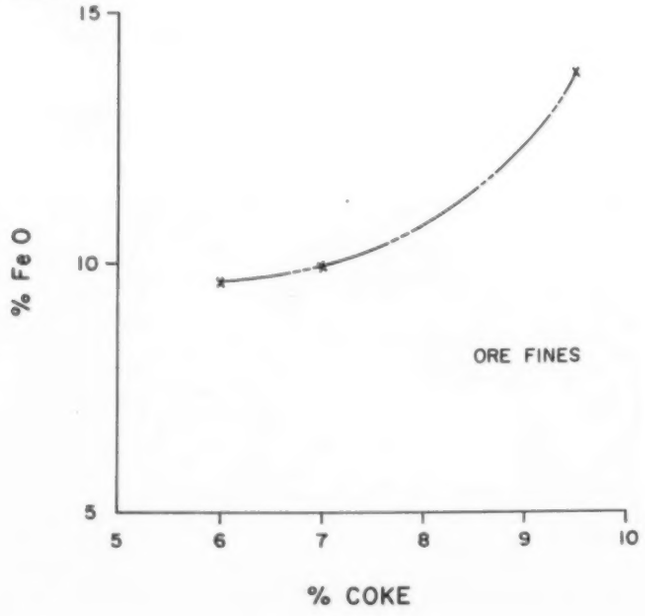
Figure 7 — Suction pressure increases production rate, but the effect is limited by the efficiency of the type seal used.

cient control and instrumentation to make such a determination properly, and that some plants simply do not have the flexibility to run at optimum conditions for the materials they are now using.

Tests which were run recently on a mix of ore fines and concentrates (with no attempt to use extremes of depth to prove the point), showed a production increase of 21 per cent at the optimum, and other tests have shown as much or more, see Figure 6. This further illustrates the necessity of designing into a new plant sufficient flexibility to cover the range of materials which the plant may reasonably be expected to handle, and also indicates that in some cases modification of an existing plant can offer attractive possibilities for increased output.

While considering the process on the grates, another natural subject for inquiry is the required air flow. Much work has been done and published on the air

Figure 8 — For economy and ease of reduction of the resulting sinter, the solid fuel should be kept to a minimum.



quantities required, but perhaps not so much on the related suctions, which vary exponentially with the flow. All other things being equal, the tests have shown that in most cases production continues to rise as the suction is increased. However, the curve is asymptotic and thus a region of marginal return must be present, see Figure 7. Considering good practice in fan design, design of gas main, ducts and dust collection system, energy cost, noise level, etc., this region is usually reached at suctions of 32 to 35 in. of water at the wind box for optimum bed depth.

Ignition of the fuel in the burden can be accomplished in various ways. The general practice is to apply heat to the top of the bed just sufficient to ignite the top layer, after which the air flow pulls the flame front down through the bed as it travels along the machine. Some mixes ignite easily, but the amount of heat required of course varies with the materials, the required ignition time usually being in the range from 20 to 50 sec at practical intensities of application. The heat is normally applied by torch burners directed on the bed, or by passing the bed under a refractory-lined radiant furnace. In order to apply the heat uniformly and efficiently, and to shorten the ignition time (thereby allowing faster machine travel and more production), it has usually been found that the moderate investment and maintenance costs of an ignition furnace are well justified. Fuel for ignition may be oil, natural or manufactured gas, coke-oven gas, enriched blast furnace gas or possibly others depending on cost and availability.

Whether self-contained or added, in the normal sintering process some solid fuel must be present to produce the required process temperature in the flame front. However, apart from fuel economy, the solid fuel content should be the lowest which can be used. Excess fuel tends to produce over-burned sinter, to promote slagging and to allow still-burning fuel to be carried beyond the sinter machine with possibly deleterious effects on screening, cooling and conveying equipment. Also, reducing the solid fuel reduces the FeO present in the product; thus producing a sinter which may be more easily reducible in the blast furnace, see Figure 8.

The solid fuel added in American practice is usually ground coke or anthracite fines, but others such as refinery wastes or bituminous fines are possible. The size and dispersion of the fuel are important. For instance, lumps of fuel would produce over-burned sinter around them and under-burned material between, while if the fuel is all finely divided a flash effect is possible wherein the flame front travels so fast that the rest of the mix is not brought up to sintering temperature. A graded size consistency and uniform distribution through the mix are desired. For normal burdens, coke breeze crushed to about $\frac{1}{8}$ in. will usually be a satisfactory fuel, provided that the means of crushing do not yield too many fines.

In Europe where the fuel cost tends to be relatively higher than in the United States, a two-layer system is sometimes used. In this system the top layer contains the normal amount of fuel, but the drying and preheating of the lower layer by the hot gas, before the flame front reaches it, permits use of less fuel in the lower layer.

Another system in growing use in Europe, which has aroused considerable interest is known as "mixed-

firing." After normal ignition a cheap gaseous fuel such as blast furnace gas is burned in a hood following the ignition furnace for some portion of the machine length. The system efficiency can be enhanced by bringing hot recuperated gas into this hood, both for combustion and as excess or secondary air. The gas can be recuperated from the following hot wind boxes, from the discharge end dedusting system, or from the sinter cooler. The objective is to replace part of the solid fuel by the additional gaseous fuel and the recuperated heat. As much as 50 per cent of the solid fuel has been replaced in this manner, and where the additional gaseous fuel is lower in cost (per Btu) than the replaced solid fuel a saving is effected. A further saving is possible with this system by virtue of greater thermal efficiency, and savings of up to 10 per cent in total Btu consumption have been realized.

Another feature of mixed-firing which may be of even greater interest to American producers is the improved quality which can be attained. This is effected in two ways: first, the reduction in solid fuel produces a significant decrease in FeO; and second, the controlled surface temperature possible with an appreciable portion of the bed hooded, greatly reduces the thermal shock and thereby eliminates the disproportionately high percentage of fines often produced in the top one or two in. of the bed.

It is not within the scope of this article to describe the many applications of sintering equipment, or modified sinter processes, to the nonferrous industries. However, one additional system which has occasional application to the steel industry may be of interest. This is known as the "fuel-less underlayer," and consists of sintering an ore mix on a layer of ore containing no fuel. This produces sinter from the top layer, while simultaneously drying and partially calcining the ore in the lower layer. Thus there is a fuel saving in the over-all flow sheet, plus the ability to screen ore which may previously have been unscreenable. This system is applicable where an ore, because of its physical makeup and/or moisture content, is not screenable at fractional sizes or requires hardening. Predrying or hardening are thus eliminated, since both functions are accomplished on the sinter machine.

EQUIPMENT

A superficial inspection of sinter plants being put into operation in 1960, as compared with those of the mid-1950's and earlier, might indicate that sintering machines have changed but little over the years, except that they tend to grow larger in the newer plants. However, in the last few years there have been some significant improvements made, even on the old reliable sinter machine. The modern spirit of scientific inquiry takes nothing for granted.

Starting with the deposition of material onto the machine, the hearth layer (of screened sinter) is not a difficult problem, but the mix burden is another matter. As already described, the most careful design may have gone into delivering to the machine feed hopper a homogenous, textured mix capable of yielding the highest quantity and quality of production. Yet much of this effort may be lost in the transfer of the mix from feed hopper to machine bed. If improperly handled the mix will segregate, and too much depth in the feed hopper, or too high a drop onto the machine, will cause compaction and decreased permeability of bed. Ideally, the mix would be placed on the machine without segregation, to form a bed of uniform depth in all directions, so gently that the maximum in-place permeability would be achieved. Even the ordinary strike-off plate would be avoided since, if it does any leveling it must produce some compaction of the top layer.

Many devices have been tried for this purpose, including swinging chutes, roll feeders, oscillating or reciprocating conveyors, belts, vibrating feeders and other devices, singly and in combination. In varying degree, all of these means permit some segregation and produce some compaction. From plant observations and many laboratory tests, it has been concluded that the best of the conventional devices is a roll feeder with material distributed across its width by an oscillating or reciprocating conveyor, and many machines are thus fed with good results.

However, there are mixes so sensitive to handling as to warrant a better feeding device. For these, an interesting mechanism has been developed, known as the roller feeder. It consists of a series of powered rolls which receive the mix and place it on the machine. While essentially a simple device, the speed, diameter, width and spacing of the rolls are all important, as is the inclination of the feeder. Properly applied this device will convey the mix very gently, distribute it uniformly across the machine and deposit it thereon with an absolute minimum drop. For a pelletized burden, a portion of the feeder can be made to act as a screen for removing fines without degradation of the pellets. Such feeders have now been installed in a few plants, some with several years' service. As an illustration of the potential benefits over the best conventional feeding methods, for some mixes, tests for one plant showed a possible production increase of up to 25 per cent.

Looking at the sinter machine itself, the materials for and design of all parts have been intensively studied in the last few years, and many changes made. Some of the factors affecting grate bar design were previously mentioned. Similarly, a thorough analysis of pallet design, including such factors as size and shape of members, mass distribution, heat capacity and creep, confirmed by tests under operating conditions, has enabled the modern designer to tailor pallets for the intended service and has made possible the big modern machines with widths in excess of 13 ft at the grates. In a pallet the end pieces, carrying the wheels, rollers, seals and sidewalls, require expensive boring and machining, while the body is a casting. Thus, particularly for the wide machines, it is logical to bolt the end-pieces to the body (or center section).

There is an additional advantage to the bolted-end construction. At the high temperatures attained in modern practice, there is a definite tendency for the pallets to sag, accentuated in the wider machines. However, after the body has sagged, say ½ to 1 in. at the center, it can be reversed. It has been found that the pallets can be so designed as to require this reversal only once. After the initial sag has taken place, they are reversed and begin to sag back toward horizontal, but by the time they are approximately level the creep rate has slowed to an infinitesimal amount and a life of many

Figure 9 — Careful design of the wind boxes and related equipment permits close regulation of gas flow.

years can be predicted. Pallets of new design, which may eliminate the need for even one reversal, are now undergoing service tests.

The sinter machine drive gear has received its share of attention, with resulting improvements. Study of the kinematics of tooth profile and guide rails has practically eliminated upward thrust and relative motion in the pallet train. Simpler means have been devised to allow gear phasing for alinement of the pallet train. Better arrangement of drive gear, better protection from dust and spillage and better materials have resulted in less wear, smoother action and less maintenance. As a result of these improvements drive power requirements have been reduced.

The size and shape of the wind boxes (Figure 9), their attachment to the machine frame and their connection into the gas main have all received attention. By applying known principles of fluid dynamics and newer data on erosion, both the pressure drop into the gas main and the wear rate due to material entrained in the gas, have been reduced. Better provision has been made for expansion, thus reducing the possibility of misalinement from that source. Also, the individual wind box dampers, which not only facilitate starting of the cold machine but permit precise regulation of gas flow, have been redesigned both from the standpoints of life and ease of operation.

The sealing of the moving pallet train to the wind boxes is obviously of great importance. However, the simultaneous requirements of providing an airtight seal between moving surfaces and minimizing friction are somewhat contradictory, so that a compromise is necessary. A number of methods have been tried, including drop-bars, sliding seals and grease seals. Until recently, the grease seal, properly applied and adjusted, appeared to be the best available. The basis for this statement is that measurements on a number of existing plants have shown in-leakage up to as much as 55 per cent of the total air at the fan, whereas measurements on a modern American plant equipped with grease seals on the machines showed this figure to be approximately 10 per cent. A recently developed spring loaded cartridge seal, however, which has been in plant service for as long as three years, is obviously superior and should hold in-leakage under reasonable conditions to well under 10 per cent.

Genuine improvements have also been made in the discharge end of the machine. With a hearth layer, there is no need for any impact to break the sinter cake loose from the grate bars, therefore means are available to separate the pallets at the discharge end and lower them to the return strand without any bumping or rubbing (and consequent accelerated wear) of pallet ends. A system of chutes and feeders to catch and convey spillage in the area where the sinter cake breaks has made it possible to design an effective enclosure, which can be exhausted through a dust collector to eliminate the dusty condition often observed around machine discharges. Proper location and inclination of the crash deck, together with redesign of the breaker teeth have eliminated pile-ups and jamming in the breaker. Some research work, supplemented by detailed observations of wear patterns and crushing action, led to redesign of the breaker arms and teeth and application of improved materials, with the result that instead of replacing arms after 40,000 to 50,000 tons, the arms (Figure 10) now have a useful life of over a million tons, while the tips need hard-facing after about 300,000 tons. The necessary replacement or repair is readily accomplished in the regular down turn.

Figure 10 — Breaking of the sinter should not produce an unnecessarily large number of fines.

In the modern plant, the reliable, uninterrupted feed of materials from the storage bins and the accurate weighing and proportioning of same is a must. Rugged belt scales, either pneumatic or electronic, are now available with guaranteed accuracies of 0.5 per cent. These can be applied to the mix belt to total the feed from several bin feeders, or to weigh belts interposed between the bin feeders and the mix belt. The number and arrangement of scales of course depends on the number of mix constituents and the flexibility required.

However, the usual arrangement has the additions of all additives, also fuel and return fines, paced from the actual total ore on the belt. Whatever the rate of ore feed, each added material is then metered at a set percentage of the ore, and these percentages can be changed at will from the control panel. Such an arrangement provides uniform mix feed at the desired rate, minimizes operating labor and can be integrated into whatever degree of automation is desired.

However, in order to make such a weighing and proportioning system function as well as to realize the potential savings in operating labor, it is necessary that each feeder deliver from its bin a uniform flow of material at the demand rate. For free-flowing materials such as return fines this is not difficult, but for others like wet, sticky ore fines the most careful attention must be given to the design, often supplemented by laboratory tests of the material through handling devices of calibrated performance. The bin cones must be steep enough (up to 70 degrees for sticky materials) to make them normally self-cleaning, the bottom opening must be large enough to prevent choking and minimize bridging, and the proper feeder must be used.

There are a number of different feeders now available, the selection for a given application being influenced by the handling characteristics of the material, the feed rate and variation, the size of bin opening, etc. For a fairly wide range of materials, the popular rotary table feeder may still be a good choice, but extremes in either direction (free-flowing or sticky) or other special conditions may dictate the use of other types. A recent development, now in use in Europe for sticky ores consists essentially of a vibrating hopper under the bin opening (for extremely sticky ores two vibrating hoppers in series are used). This method permits use of a large opening at the bin, and by keeping the material "live" and moving, trains it onto a flat belt which delivers it to the mix belt. The feed rate is regulated by a scale on the flat belt.

Depending on the materials and plant location, supplementary means may be needed to assure reliable and uniform flow. Where materials are received partially frozen, or where wet ore fines are handled during freezing weather, it is often necessary to enclose and heat the incoming belts and the storage bins building, possibly with steam coils or strip heaters on the bin cones as well. Another useful device where occasional vibrating or rapping of bin cones is required is to control the vibrators by a simple sensing device in the material flow from the feeder. Any interruption in material flow then immediately and automatically starts the vibrators. Along the line of loosening material in the bins, there is also available a device consisting of hollow rubber panels which are alternately inflated and deflated, thereby breaking loose material from the bin walls much as ice is broken loose from airplane wings.

Screening of the sinter is necessary to obtain the clean, sized product needed for optimum furnace operation and to separate return fines and hearth layer. There is a sufficient background of experience so that screening of the cooled sinter into the required fractions can be readily accomplished by proper application of available equipment. However, hot screening, being a relatively recent innovation, has introduced new problems and requires careful attention.

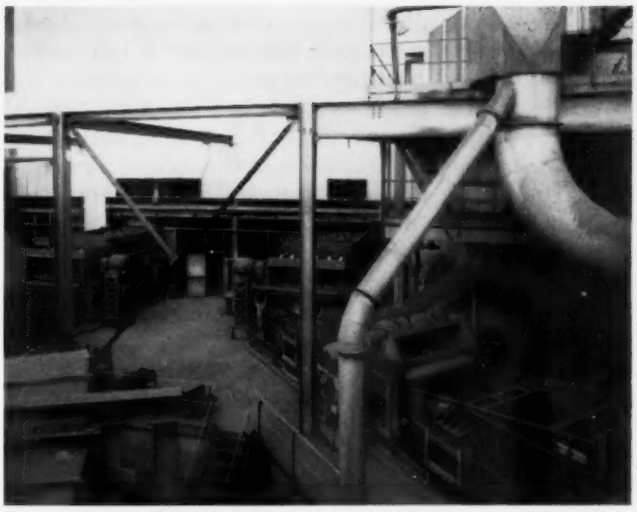


Figure 11 — Hot screening is necessary to produce hot return fines which improve production and process efficiency.

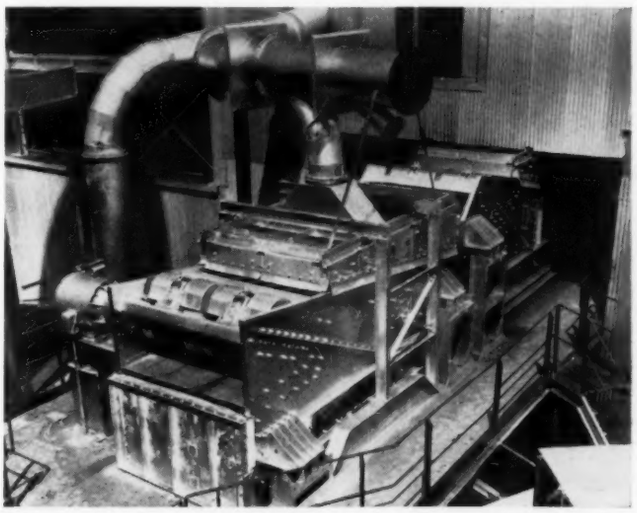


Figure 12 — Screening of the hot sinter opens the bed and reduces the cooling load.

All modern plants incorporate hot screening and air cooling of the sinter. From a process standpoint, the hot return fines improve bed permeability and production, and produce some improvement in thermal efficiency. The requirement for air cooling also makes hot screening desirable, both to reduce the cooling load, make a more open bed for passage of cooling air, and remove the fines which would otherwise become airborne and create a dust problem and excessive fan wear (or require expensive collection).

The manufacturers who furnished the early hot screen installations found that in all cases the temperatures had been underestimated. This resulted in structural problems, in expansion problems, in difficulties in holding together the various components and in accelerated wear. Without going into the numerous details of these problems, it is suffice to say that continuing observation and modification, together with both laboratory and plant trials of new design features, have resulted in steady improvement to the point where reliable hot screens can now be obtained from more than one source, see Figures 11 and 12. The proof of this can be obtained from the

maintenance and downtime records of several plants. Incidentally, much credit in this respect is due to the operators and maintenance supervisors of some of the earliest plants to get these installations. Almost without exception, these gentlemen recognized early that this matter was of vital importance, and cooperated whole-heartedly with the manufacturers and plant designers to make possible the continuing programs of observations, modifications and trials which were required.

Since it is impractical to convey hot sinter over any appreciable distance or store it in sizable quantities (without rehandling), some form of cooling is necessary. Even for normal sinters, the advantages of air cooling have long been recognized, and the general production of fluxed sinters have made it a necessity, at least in the presently-accepted over-all setups. Air coolers are now not only incorporated in all new plants, but are being added to a number of older plants.

Basically, the function of a sinter cooler is simple: it is required to cool sinter so many degrees at such-and-such a rate, continuously, with the lowest possible investment, operating and maintenance costs and the least possible degradation of the sinter. The practical attainment of these goals has required some years of design and research, laboratory testing, plus records, measurements and full-scale tests on the early operational coolers.

Several types of coolers have been built: quiescent bed, both circular and straight-line; induced-draft and forced-draft; and moving bed, circular and forced-draft. The wealth of data obtained from all of these now permits selection and design with confidence that the cooler (Figures 13 and 14) will be exactly right for its particular application. Factors affecting cooler selection are: plant location and layout; available space; type, temperature, size and tonnage of sinter; energy cost; conveying and storage requirements of the cooled sinter, etc.

The quiescent bed cooler involves problems of loading, both as to even distribution across the trays and as to size distribution vertically (to prevent fines gravitating to the bottom, as they naturally tend to do). Nevertheless, solutions to these problems are available, and this type of cooler has much to recommend it. It causes very little degradation of the sinter and, provided the sinter is reasonably clean (screened) and the air velocity through the bed properly controlled, remarkably little dusting. The size of cooler, bed depth, retention time, fan pressure or suction and air velocity can be nicely balanced. For a given production rate and a required temperature drop, the quantity of air which, for some temperature rise and transfer efficiency, will theoretically carry off the necessary quantity of heat is easily calculated. However, it must be remembered that, while heat can be removed very quickly from sinter surfaces, it can be taken away from a lump only as fast as it will come out of the lump. Therefore, it is necessary to know the thermal gradient vs time and temperature, and to determine the minimum retention time required for a given size lump. Thus, from a cooling standpoint, sinter of uniform size would be most desirable. This is obviously not possible in practical operation, but recent developments in

Figure 13 — Air cooling of the sinter can be accomplished by any of several types of coolers. Shown is induced-draft circular type.

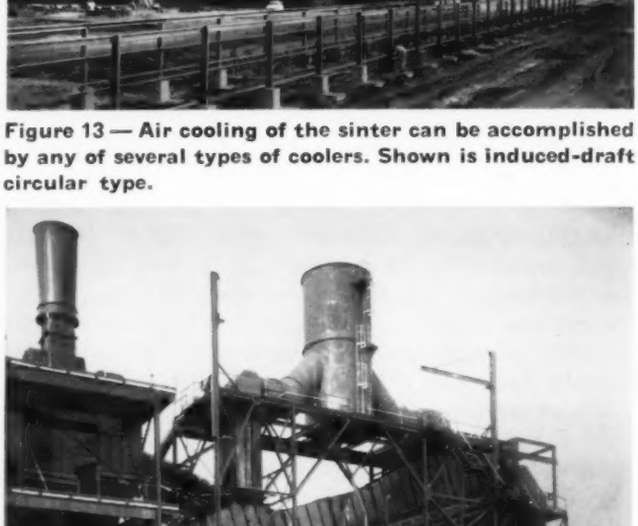


Figure 14 — Cooler shown is induced-draft, straight-line unit.

breaker design have made possible the production of hot sinter much more uniformly sized than formerly.

Another factor modifying the amount of cooling air required is the exothermic reaction which takes place in the first part of the cooler, where conditions are right for exposed magnetite to oxidize to hematite, thus producing heat to be removed over and above the calculated cooling load. On full-sized coolers by taking sufficient simultaneous measurements to enable a complete heat balance to be made, in some instances the additional heat from this source has been determined to be in excess of 100,000 Btu per ton of sinter.

What has been said above on quiescent bed coolers generally applies also to moving bed coolers, which can offer some savings in space, investment and operating cost. With this type of cooler, however, it has not to date been possible to avoid severe degradation of the sinter. A new design shortly to be tried in a plant installation appears quite promising, and if successful may retain the savings while eliminating the undesirable features.

The mechanical designers have also contributed much to the modern cooler, such as improved seals, air-locks (where the sinter enters and leaves the cooling hood), drive, means for loading the hot sinter gently

and evenly on the trays and means for unloading the cooler without plowing, jarring or excessive drop.

In the quiescent bed type, induced-draft coolers have several advantages over forced-draft coolers, such as simplicity, economy, cleanliness and thermal efficiency. However, although with the correct balance between cooler size, bed depth, fan suction and air velocity, the unit dust loading is very low (not requiring dust collection in most cases), the very fine material is of course airborne, and because of the large air volumes this can create an abrasion problem on the fan blades. For a while this was a problem with the earliest induced-draft coolers. With axial-flow fans, solid airfoil blades, solid curved blades, flat blades, hollow airfoil blades and various coatings and surfacings were tried. This problem can be solved with large, low-speed centrifugal fans, but for this type of service the axial-flow fan requires less space, is lighter weight, lower cost and is more efficient. Provided the axial flow fan is properly applied, and that certain postulated conditions as to blade design, material, speed and configuration are met, it is now definitely established that full advantage can be taken of these savings without the problem of wear.

Obviously, a large volume could be written on the rest of the equipment found in a sinter plant, but the major items in the heart of the process flow have been covered, albeit very briefly. For the purpose of this review, it will perhaps suffice if two more important items, mixing or balling drums and coke crushing, are only lightly touched on.

The function of a drum largely determines its design: whether it is for primary mixing, for secondary mixing and fluffing, or micro-pelletizing, or for a pelletized burden. The required function, for the tonnage and particular materials involved, enables the designer to set the retention time, degree of filling, size of drum, slope, speed, power required, etc. Here again, the additional knowledge gained from the extensive research and large scale operations of the last few years permit the effective design of equipment for a specific function. As an example, there are plants where the secondary drum is not used because it has no measurable effect on quality or quantity of production, and still others where such drums could as well be by-passed. In some of these cases this is due to changing materials; in others, to improper selection of the original mixing system; but in some cases it is simply because the proper degree of filling was not known at the time, and the drum cannot now be filled to that degree without major modifications. For a wide range of materials, a secondary drum should be filled to about 12 to 14 per cent of its volume. At much below that range, no pelletizing action can occur, and at much above the material tends to compact.

Figure 15 — The main exhaust fans can be a source of considerable noise.

An important recent advance has to do with the support of drums. A drum is a large and heavy piece of equipment, up to 13 ft in diameter and 50 ft in length. Because of its relatively slow speed and heavy mass, it requires rigid and costly foundations to hold vibration of the supports to acceptable levels, otherwise excessive tire wear is likely to result, as well as possible effects on adjacent structures and equipment. There are some plants where it is very costly and very difficult to maintain the steel tires on the drums.

The recent advance consists of mounting the drum on rubber tires, which also drive the drum, rather than the conventional steel tires and trunnions with ring gear drive. There are now a number of successful installations of this type. Pneumatic tires, water-filled tires and solid rubber tires have been used. On the basis of several years' experience, solid tires are now preferred, because of wear and because the careful maintenance of equal inflation pressures is not required.

Ground coke for sinter fuel has for many years been produced by rod mills, and since these can produce coke of acceptable size consistency in open circuit, they are still a reliable (if costly) source of the solid fuel required. It has been found that force-feeding the mills by screw feeders, and air-sweeping them can considerably increase their capacities. Nevertheless, they require large space and initial investments and the operating costs (including rods and liners) are fairly high.

Certain types of impact crushers have been tried for this service. They do offer potential savings in both investment and operating costs, but require the additional complications of closed-circuit operation with screens. Also, they produce too high a proportion of fines (minus 100 mesh), and therefore have not been satisfactory.

Several plants in Europe are using a method for crushing coke which certainly saves space and initial investment, and appears to be satisfactory. It consists of two sets of smooth, high-speed rolls in series, and requires little more than two conveyor transfer points for its installation. The rolls require periodic refacing and grinding, but spare rolls are readily inserted, and it appears that the operating costs should compare favorably also.

PLANT

In a few short years the sinter plant has changed to a vitally important, integrated link in the process chain from raw materials to hot metal. Looking at the modern plants built from about the mid-1950's on, it appears that in a few cases the pendulum may have swung a little too far, in that unnecessary space and

features were provided. However, other plants of this period appear reasonable and some of the latest plants, starting operations in 1960, seem to be well designed for their function, with space, equipment and facilities adequate for their purpose, but not wasteful. In any event it is very evident that the function and character of sinter plants has changed tremendously in a decade or so, and in keeping with the announced scope of this article, it is not here intended to write a treatise on plant design, but rather to examine recent and current changes and trends.

The growth in functional importance of the sinter plant has led naturally to the assignment of prime space to it rather than some inconspicuous corner. A logical location, where possible, is between the ore yard and the blast furnaces, but in many existing plants the prior development or crowded condition makes this impossible, in which case the very best possible available location must be found. The point is that such a large (and increasing) proportion of the furnace burden is now handled through the sinter plant that the best location involves careful study of an integration into the material handling of the over-all plant, for both present and anticipated future needs. This involves the cooperation and mutual planning of the raw materials and blast furnace divisions, power and fuel, plant engineering, and the sinter plant designer. Today, the trend in materials handling, as well as in all other phases of plant design, is to minimize operating and maintenance labor insofar as additional investment cost can be justified. Some of these considerations in the process operation of the plant were discussed earlier.

In addition to modern equipment and automation, labor cost may be reduced by increasing its efficiency. This may be accomplished by job planning and by providing acceptable environmental conditions. Job planning must start right in the plant layout stage. A manning chart should be made up and studied concurrently with the layout development. When examining the function and specific duties of each man at this stage, it will often be found that operators can be saved at little or no cost by rearranging controls or equipment, adding remote control here, combining or grouping functions there, etc. Depending on the physical layout and with the aid of mimic panels, remote controls and indicators, the outside materials receiving man may be able to fill the storage bins, and the sinter screen attendant may be responsible for product load-out, screening, dispatch and storage of fines and hearth layer. Numerous other possibilities will suggest themselves in this kind of study.

The need for acceptable environmental conditions today is well recognized. There are now few areas in which it would be possible to get desirable men to work regularly under the conditions which prevailed in sinter plants not many years ago. Humanitarian considerations aside, this reason alone would dictate reasonable working conditions today, and in addition, an increase in efficiency with an improvement in working conditions has been thoroughly demonstrated.

The modern plant must be clean, with all screens, transfer points and other dust sources enclosed, and where necessary exhausted to the outside. It must have good lighting, light colors, clear instrument dials, and any obstructions or potential danger points (where unavoidable) prominently lighted and painted in loud warning colors. It must be well ventilated in summer and have operating area temperatures maintained at comfort levels in winter. Also, noise levels must be controlled and should be at comfort levels in regular operating areas.

A similar trend is evident in the external conditions about the plant. Experiences of the last decade have shown that the effect of the plant on the health and temper of the public must be carefully considered. Most states now have definite laws regarding water pollution, and many communities have in effect, or are preparing, stringent regulations on atmosphere pollution. Definite anti-noise laws are not so common, but community governments or citizens' committees can successfully bring suit when a nuisance can be shown. Even in relatively sparsely-settled areas, recent experience has demonstrated that conditions must be maintained which, if not up to the tightest city standards, are still reasonably good. Thus, entirely apart from considerations of public relations (good will), and even though few extra tons of sinter will be produced thereby, a sizable investment in the equipment needed to maintain good external conditions may be an absolute necessity for operating a plant.

All of this means that careful planning and design are needed to meet these criteria. For the atmospheric condition dust collection is required at a number of points. In order to avoid a multiplicity of collectors, it is usual to collect the dust from a number of pick-up points in an area (such as machine discharge, hot screen and feeder, cooler loading and discharge, hot fines feeder, adjacent transfer points, etc.) into one collector. Such areas always include the gas main, the machine discharge end and the sinter screening station, and may include others in a given plant, depending on the facilities, arrangement and criteria to be met.

With proper sizing and design of gas main and collectors, adequate protection of the fans and good cleaning at the stack can be accomplished by dry mechanical collectors, satisfactory in many locations. Where the most stringent regulations (such as a maximum discharge of 0.05 grains per standard cu ft) apply, another type of collector must be used. There are several ways of accomplishing this degree of cleaning, but for this point, in view of the gas volume and also pressure drop considerations, the electrostatic precipitator seems the logical choice. It is true that several early sinter plant precipitator installations had troubles, but these problems have now been solved. Also, the operating conditions for a precipitator at this point are now much improved, due largely to the improved seal previously mentioned which, by practically eliminating infiltration, keeps the gas temperature above the dew point at all times except during startup.

For the plant dedusting systems, such as the machine discharge area or the screening station, the dust loadings are such that dry mechanical collectors cannot produce a clean stack. This leaves precipitators, bag filters and scrubbers, all of which are now being used successfully, when properly applied. In the case of the scrubber, unless a settling pond draining into ground remote from any water supply is available, the

dirty water must be cleaned before it can be discharged into a waterway. This requires capacity in existing clarifiers for the additional flow, or else new clarifiers.

With regard to noise, the main exhaust fans (Figure 15) are the worst offenders. To be sure there are many other sources of noise around a plant, such as cooling and dedusting fans, vibrating screens and feeders, bin vibrators, rod mills, trunnion-mounted drums, and so forth. However, these others either operate in the tolerance zone or are amenable to treatment. The main fans are a much more difficult problem.

Some reduction in noise can be effected in the design of the fan itself, as for example in the number and angle of blades, the scroll configuration, and the shape and location of cutoff. Duct work can be stiffened or insulated and, at some expense, the fans can be set in sound-proof enclosures. These measures are effective for the plant personnel and people nearby. Unfortunately, they may do little to prevent a nuisance to people one or five miles away. This is because the high energy level imparted by the fan to the exhaust gas is carried up the stack, and may be reflected or concentrated by atmospheric and topographic conditions. When such a nuisance exists, it may be necessary to install some form of energy absorber in the stack or breeching. Such measures will reduce the energy level, but they are expensive to install, wasteful of fan horsepower and difficult and costly to maintain. Anyone producing a simple, reliable and inexpensive fan silencer would find a ready market for his device.

The amazing sintering progress which has been made in the last decade has naturally gone hand-in-hand with the advances in blast furnace technology. Since still more major blast furnace advances are just around the corner, with seemingly insatiable demands for more and better feed, another decade of significant advances in sintering and related processes can be easily foreseen. ▲

Available Translations

As a service to readers of the *Iron and Steel Engineer* a list of translations from foreign articles is being printed intermittently. Articles selected for this listing will be those of primary interest to the American steel plant operator. The papers may be obtained from the British Iron and Steel Industry Translation Service, The Iron and Steel Institute, 4 Grosvenor Gardens, London, S.W. 1, England. All correspondence concerning price, ordering and so forth should be directed to that address.

1493 WEYEL, A., et al.: "The Production of Power and Blast in the Top Gas Power Plant of an Iron and Steelworks by Means of a 14-mw gas turbine," *Stahl u. Eisen*, 1959, Oct. 15th, pp. 1471–1478. Plants for producing power, blast and steam in the Klockner-Huttenwerk Haspe in the year 1945. Results of expansion in raw steel production and increased scope. Immediate program and considerations in respect of basic improvement of power generating plants. Gas turbine for increased generation of power by the works itself and for the production of blast for blast furnace. Open or closed cycle for the gas turbine. Features of the 14-mw gas turbine plant. Comparison of costs between gas turbine plant and other means of producing power and blast. Building the 14-mw gas turbine plant (weight:800 tons) on the site of an old 2.2-mw blowing engine (weight :900 tons). Putting the gas turbine plant into commission and experience gained during operation of same. (Author's summary.)

1680 DAVYDOV, V. I., & YU. K. PUZYREVSKII: "Forces Operating in Cold Roll Forming," *Stal' Rolling & Tube Manf. Supp.*, 1959, pp. 95–103. The vectors and pressures involved are identified and formulated, and a simplified calculation of power requirements is presented with a procedure for approximate calculation. (Abstract preprinted from *J.I.S.I.*)

1412 BILLIGMANN, J., et al.: "Measuring the Degree of Reduction in Temper Rolling," *Stahl u. Eisen*, 1959, July 9, pp. 977–989. After discussing the relation between the reduction obtained by skin-rolling and the properties of deep-drawing steel and strip used for packaging, the authors review methods for the measurement of the properties after the skin-pass. They discuss the bases of the measurement of the deformation in skin-rolling, which is entirely different from that employed in normal rolling practice. Design and operation of modern equipment for measuring the extension of the strip in skin-rolling, accuracy obtained, and effect of rolling speed are described in detail (46 refs.). (Abstract *J.I.S.I.*, 1959, December, p. 388b.)

1705 NETTER, P.: "Production, Properties and Economic Importance of Rimming Open-Hearth Steel," *Neue Hutte*, 1960, Feb., pp. 63–69. Advantages and disadvantages of killed and rimming steel. Strength properties and notch impact strength. Importance of rimming steel for the national economy. (Author's summary.)

1619 PAPULI, G.: "Modern Forging Manipulators," *La Metallurgia Italiana*, 1959 (3), pp. 94–100. The advantages derived from the mechanization of forging plants through manipulators are examined. After a short historical survey dealing with the development of the quality and power of manipulators and the manner in which they have quickly become popular in the last ten years, the article makes a comparison between the various operating types and gives data about the large new 120-ton manipulator installed in the steel works of the Terni Co. Examples are also given of the plastic transformation cycles of the steel, as obtained with the manipulator, in comparison with the traditional system. (Author's summary.)

Sharon Steel To Install Kaldo Furnaces

SHARON Steel Corp. will become the seventh company in North America to make steel by a basic oxygen process; however, Sharon will be the first company in the U. S. to install Stora Kaldo furnaces.

Invented by Professor Bo Kalling, Director of Research for Stora Kopparsbergs Bergslags, A.B., the Stora Kaldo process was put into operation in Sweden in May 1956. Sharon expects to tap the first heat from the new $17,500,000 facility, which will be built by Dravo Corp. at the Roemer works, Farrell, Pa., in the fall of 1962.

The 2-furnace Stora Kaldo installation will have an initial capacity of approximately 1,000,000 ingot tons annually. Provisions are made in the design of the plant for an additional furnace that could double this output.

As a result of carefully controlled quality tests over the full range of carbon steel analyses produced in Sharon Steel Corp.'s open hearth furnaces and in electric, L-D and Stora Kaldo furnaces, it was concluded that steel made by the Stora Kaldo method would best supplement the present range of specialty steels produced. For with Stora Kaldo, Sharon Steel Corp. will add a quality product without upsetting the economics of their existing melting, hot rolling, finishing, blast furnace, coking and mining operations.

With the range of materials used at Sharon and for the steel grades now produced and for the grades to be produced, Stora Kaldo will provide in the finished product extremely close control of phosphorus, sulphur, nitrogen, oxygen and nonmetallic inclusions.

Based on work in Sweden and France, it has been determined that three of the most critical advantages of the Stora Kaldo process are heat economy, temperature control and metallic yield. Extra heat results from the full oxidation of carbon and makes it possible to melt relatively larger quantities of scrap when the economics justify it. Otherwise, ore is used as a coolant and for the control of temperature. Instrumentation will include analog computers for establishing operating criteria.

Professor Kalling, inventor of the process, will serve as a consultant during the construction and early operation of the new furnaces.

The new melt shop, complete with charging, furnace and teeming aisles, along with a scrap and slag handling bay, will be housed in a building 500 ft long by 244 ft wide. The plant has been designed to expedite the movement of raw materials and the finished steel ingots. The furnaces, 25 ft long and 18 ft in diameter at the center, will rotate in a cradle at speeds varying up to 27 rpm, at an angle of 17 degrees. High-purity oxygen will be injected into the vessels through water-cooled lances mounted in the movable exhaust hoods which fit over the mouths of the furnaces. By using wet scrubbers in the dust collection system, air pollution is closely controlled.

LOW-PRESSURE PROCESS PLANT TO SUPPLY OXYGEN

The on-site air-separation plant to be constructed by National Cylinder Gas Div. of Chemetron Corp., Chicago, Ill., will be the first in this country to use a new, simplified process for producing large quantities of liquid as well as gaseous oxygen. Construction of this facility will begin immediately.

The unit also will be the first NCG plant which, in addition to supplying oxygen, will deliver large quantities of high-purity nitrogen to a steel mill.

Dravo Corp., Pittsburgh, Pa., will design and construct the plant, which will be based on the process of Gesellschaft für Linde's Eismachinen AG, Munich, Germany. The process is said to be characterized by simplicity and safety of operation.

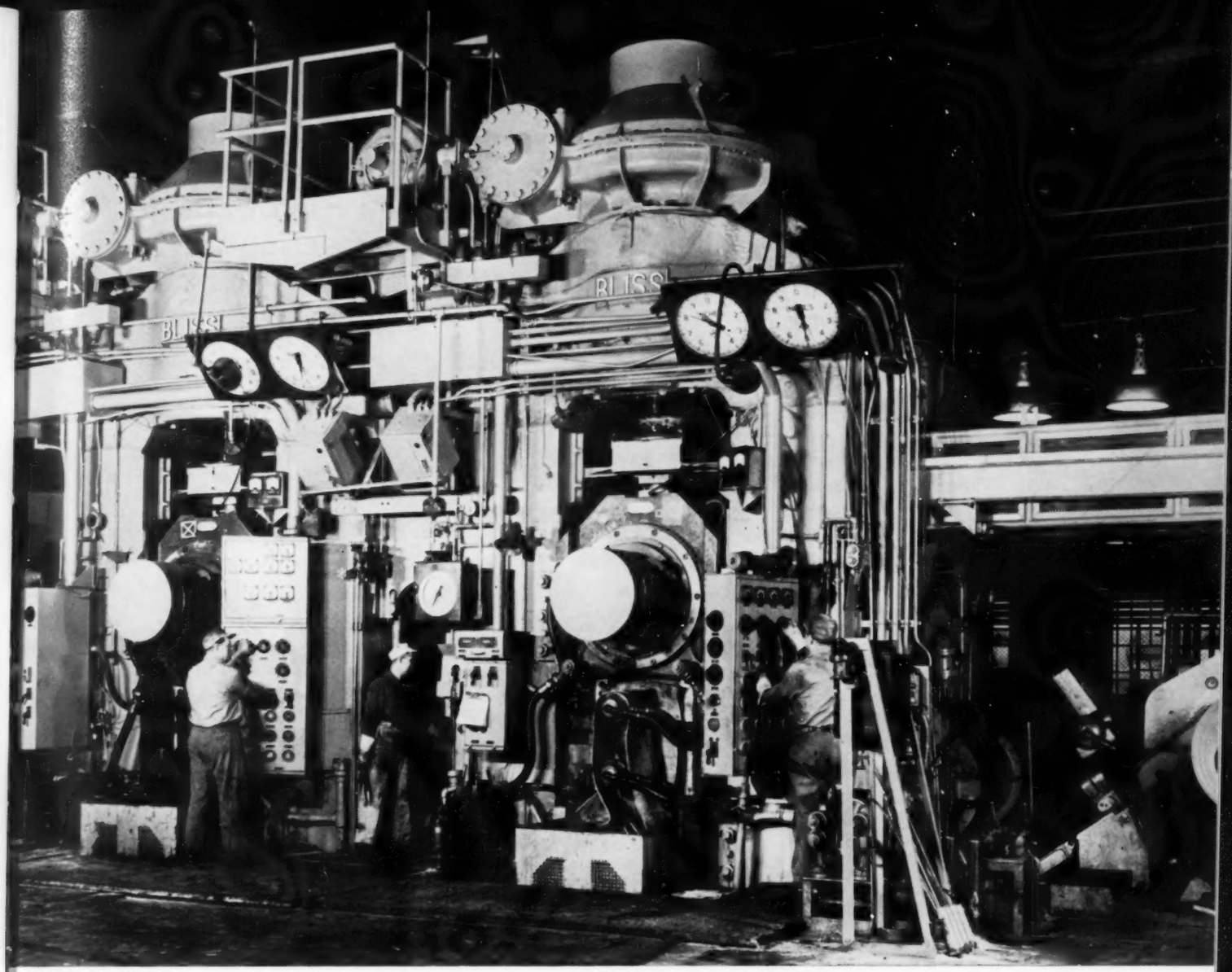
The plant will have a capacity of 370 tons a day of high-purity air separation products in both liquid and gaseous form, and is expected to be in operation by late 1962. Plans include provision for construction of a second unit of equal capacity at a future date.

Gaseous oxygen produced in the versatile plant will be used for the new oxygen steelmaking process and for general mill applications, and the nitrogen will be used to supply a high-quality annealing furnace atmosphere. The liquid oxygen and nitrogen output will be transported and sold to other users in the area.

The ability to supply large quantities of liquid oxygen without extra refrigeration equipment or compressors is said to be unique, and is accomplished by adaptations of the basic low-pressure process.

Booster oxygen compressors and large-capacity gaseous and liquid storage vessels will accommmodate fluctuating mill demands. When gas demand is low, excess oxygen will be stored in these vessels, and will be used during peak demand periods.

A single-story building will house control instruments and compression equipment. The cold box, gaseous oxygen, liquid oxygen and liquid nitrogen storage vessels, and a cooling water tower and pumps will be adjacent to the building. ▲



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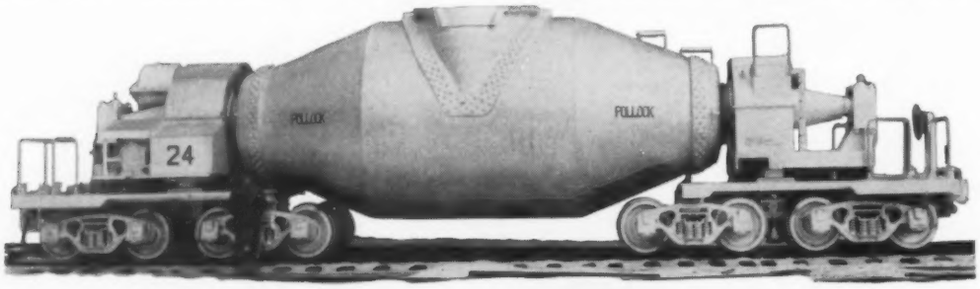

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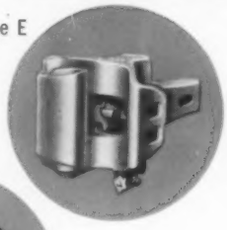

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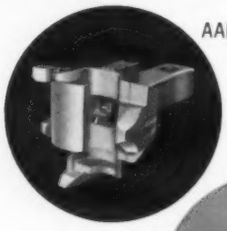
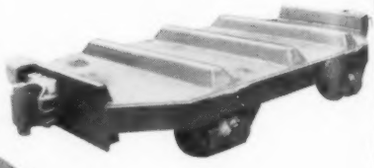
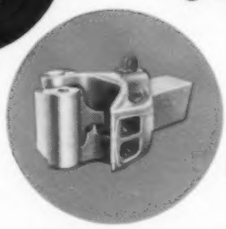




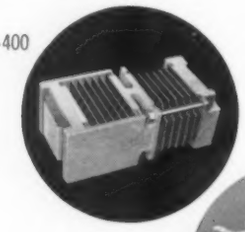
Sharon-10A

NATIONAL COUPLERS

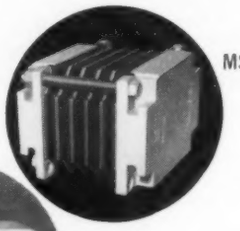


National AP

MF-400



NATIONAL RUBBER DRAFT GEARS



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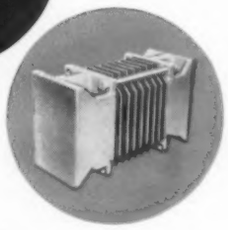

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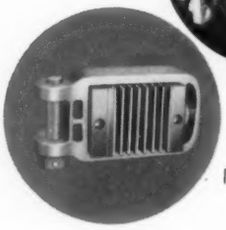
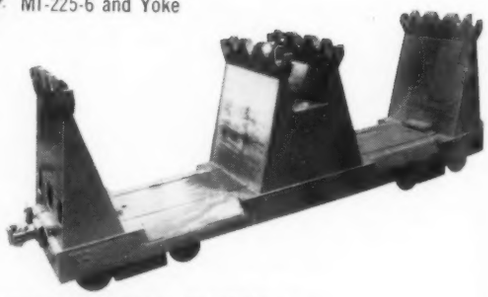


MI-225-6 and Yoke



Transportation Products Division

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A-2361A

Blast Furnace Burden Level Measured By Nuclear Gage

A CONTINUOUS nuclear measuring system, for the control of the burden level of blast furnaces, developed by Republic Steel Corp. will be manufactured and sold by Cutler-Hammer, Inc.

This control system, called Stockray, provides a further step toward obtaining optimum blast furnace performance, for it is a continuous measuring device for determining burden level. With it the mechanical hoist type stockline gaging system can be eliminated. Stockray is a highly efficient gaging system using nuclear techniques to detect and monitor burden level.

The electromechanical research department of the Republic Steel Corp. developed Stockray, and installed the first system on an operating blast furnace in Chicago in November, 1958. The second system was installed at Buffalo in August, 1960. Both systems have been in continuous operation and have never required a furnace shutdown for maintenance.

Cutler-Hammer, Inc., has signed licensing agreements with Republic Steel Corp. enabling them to design, build and sell systems based upon this design with permission to make improvements where possible.

OPERATION

The system uses an arrangement of radioactive sources, emitting gamma rays on one side of the furnace, and a corresponding arrangement of radiation detectors on the opposite side. The detectors recognize the presence or absence of gamma radiation directed from the sources. When the stock inside the furnace obstructs a radiation beam, it obscures the signal to the corresponding detector.

The output from each radiation detector box is fed to its amplifier and control circuit located in the main control cabinet. Also in the cabinet are the a-c regulated power supplies, recording equipment, indicating lights, switching networks and detector test circuits. All circuits use solid-state devices for reliability, space saving and simplicity of cooling. A signal light arrangement representing each stock level detector indicates when the burden drops below each detector level. By proper arrangement of the lights, a graphic distribution of the stock level can be seen. Bell dumpings can be indicated on the recorder.

The arrangement of sources and detectors determines the significance of the signal light indications. Various mills might desire different configurations and Stockray fully meets this requirement. One typical arrangement consists of four separate sources and detectors alined in the East-West direction, and three separate sources and detectors in the North-South direction. The specific gaging levels are:

Distance from bell, ft	*Beam port direction*
6	East-West
7	North-South
8	East-West
9½	North-South
11	East-West
12½	North-South
14	East-West

RADIATION SOURCE

Gamma rays are used both for their penetrating power and safety. The gamma-ray emitter used in this device is cobalt 60, which cannot induce radioactivity in any material it strikes. Its half life is 5.3 years, and the source material can be used without replenishment for at least five years of continuous operation. The source holder is made of lead and stainless steel and weighs 500 lb. The space required for the holder is 14 in. high by 18 in. wide by 12 in. deep. With its shutter closed, the holder is approved for shipping and the radiation level is at a safe value for handling purposes. The strength of the source is low enough that the holder can be small enough for safe and practical use. When the source holder is bolted to the furnace and ready for operation, the shutter is opened, thereby displaying a warning flag. Under this condition, the radiation level meets all Atomic Energy Commission requirements for personnel safety.

RADIATION DETECTOR

The detector box is located on the opposite side of the furnace from its source. Its dimensions are 6 in. high by 6 in. wide by 12 in. deep, and its weight of 30 lb permits easy handling and mounting in the installation phase. The detector is housed in a weatherproof, cast-iron enclosure upon a base for bolting to furnace brackets. Each unit consists of one draw-out type module containing all the components. It detects the radiation transmitted through the furnace from the source on the opposite side. Geiger-Muller tubes of stainless steel construction are used as the detection device. They are highly dependable components and have an extremely long life. Incorporated into each detector unit is a minute source to check for proper detector and associated

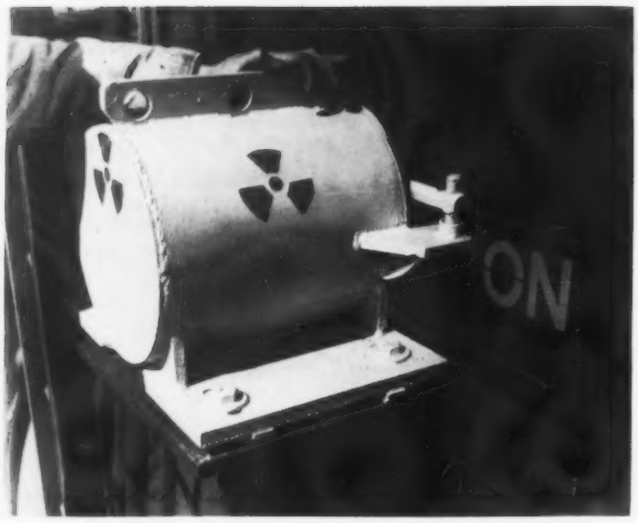


Figure 1 — The source is fully enclosed, lead shielded, and meets all AEC requirements for personnel safety.

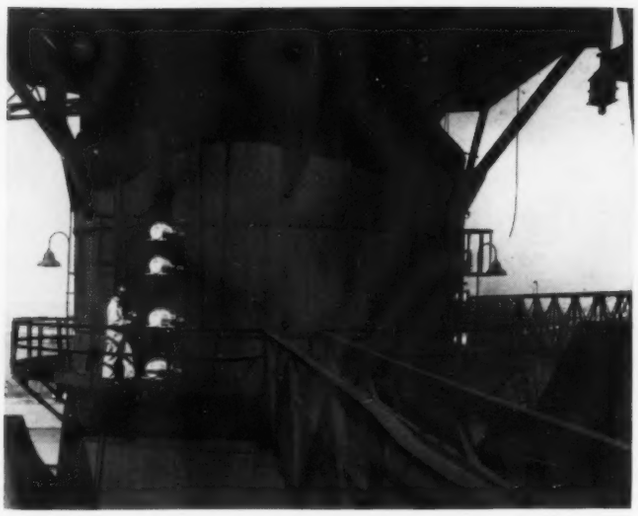


Figure 2 — Arrangement of sources and detectors will vary with the amount and type of information desired.

amplifier operation. It is operated from the main control cabinet to eliminate trips to the top of the furnace for this purpose. The half life of the check source is hundreds of years. Licensing by a governmental body is not required for these minute sources. Each detector requires only 115-volts input, eliminating the need for high-voltage runs to the furnace top. The removal of the modularized detector unit can be performed under adverse weather conditions by unskilled help.

MAIN CONTROL CABINET

The main control cabinet is normally located in the furnace instrument room at floor level and contains the amplifiers, regulated a-c power supplies, recording equipment, indicating lights, test circuits and switching networks for remote indicating and recording stations. Only solid-state devices are used. The enclosure is of the NEMA 12 type, is sealed against dust and dirt and has a front opening. Each detector circuit has its individual amplifier and control channel in the main console and is modularized for ease of maintenance. If one or more channels should require maintenance, the system will still operate but with less effectiveness. The entire system can be tested and calibrated from the control cabinet, thus eliminating trips to the top of the furnace.

Maximum flexibility is possible with this system, for the number of sources and detectors, and the number of indicating and recording devices can be varied.

The dimensions of the cabinet depend upon the number of sources and detectors, and upon the indicating and recording equipment desired. The normal size is 72 in. high by 30 in. wide by 24 in. deep. No external ventilation is required for cooling purposes. The voltage requirement is 1151 volts, 601 cycles alternating current.

INDICATING AND RECORDING EQUIPMENT

The number of level lights on the control panel is dependent upon the number of sources and detectors. Since a typical installation will incorporate seven sources with three mounted 90 degrees from the other four, a general indication is given of the distribution or contour of the burden. If desired, additional light panels can be supplied for remote indication in other locations, such as the cast and stock houses. Recorders can be mounted upon the main control cabinet and in remote locations. They can be of the 24-hr circular-chart type or the continuous-strip type, depending upon preference.

RADIATION BEAM PORTS

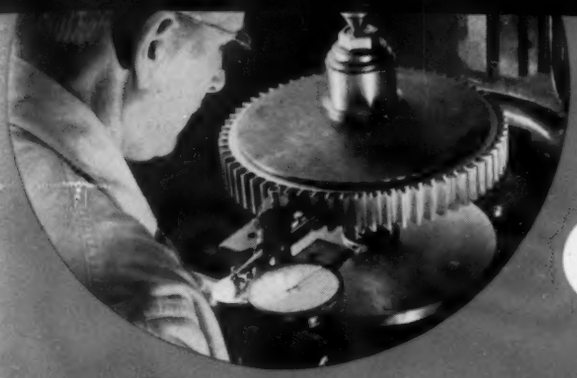
The shell of a blast furnace is as much as 4 ft thick. It is impractical for the nuclear source to be large enough to penetrate the full furnace thickness because of the high cost and handling problems with the shielding required to protect workers from incidental radiation. Stockray employs a system of beam ports with baffles to permit a far easier transmission path from a safe and practical radiation source.

The present installations incorporate two types of beam ports within the furnace linings for transmitting radiation efficiently without the risk of gas leakage or weakening furnace walls. One design consists of steel tubes with welded plates at each end. These are used in the wear-plate section of the furnace where lining erosion does not normally occur. The other design uses special fire bricks with lengthwise holes filled with dust-tight, gas-sealing thin stainless steel baffles. This type of port is installed wherever the furnace lining is not protected by wear plates.

INSTALLATION

Installation involves two phases: radiation beam ports and the nuclear gage equipment. Radiation beam ports can be installed only when the blast furnace is being relined or during the construction of a new furnace. The installation of Stockray equipment can be made either during the reline or later when the blast furnace is back in operation.

The proper design and installation of ports is essential to the correct functioning of Stockray. Once the ports are in place no changes can be made until the next reline. Normal furnace lining shifts should not affect this system when the job is done properly. ▲



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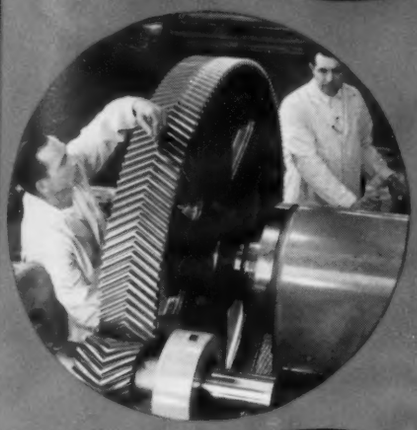

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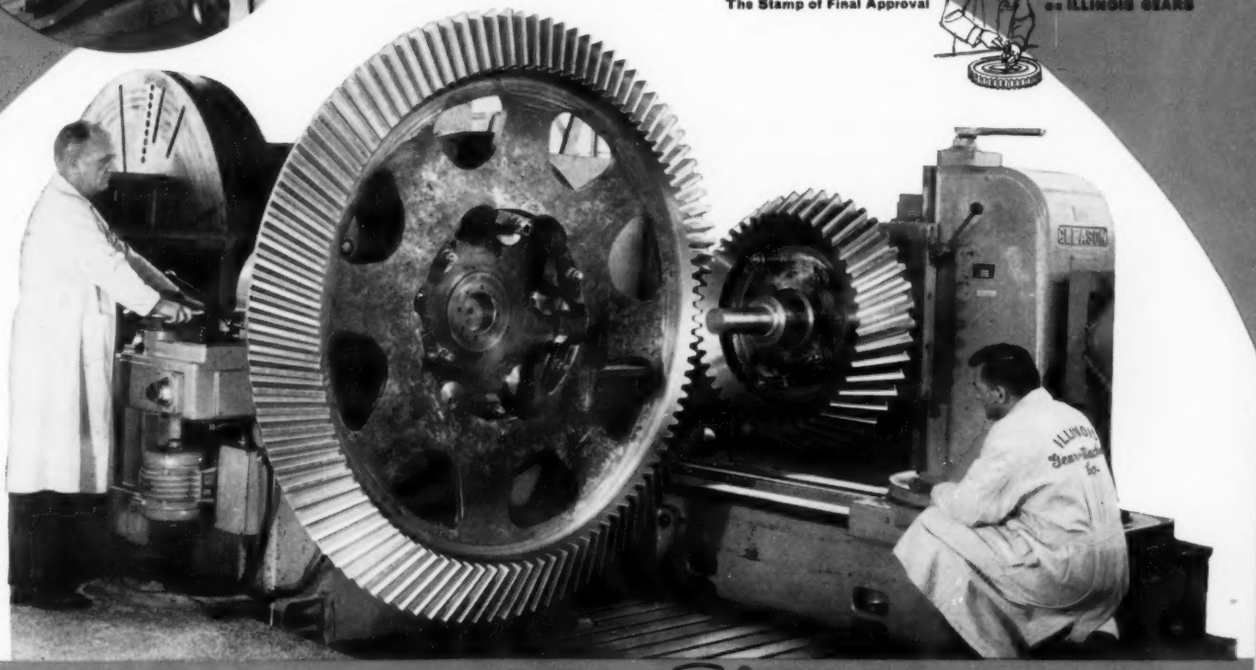

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Bethlehem Steel Expands Its Vacuum Cast Production

EXPANSION of its product line forged from vacuum cast ingots was announced by Bethlehem Steel Co. Already producing all hardened steel rolls from vacuum cast ingots, Bethlehem reported that all steam turbine rotor and spindle forgings as well as turbine powered electric generator shaft forgings will henceforth be manufactured from vacuum steel.

The company's experience proved the superiority of vacuum cast forgings subject to unusual service requirements over those made from air cast steel. Since announcing that all hardened steel rolls would be made from vacuum cast steel, Bethlehem has supplied several thousand rolls for both ferrous and nonferrous industrial users. During the past several years a large number of steam turbine and electric generator shaft forgings have also been made from vacuum cast steel with outstanding improvement in quality.

Through vacuum casting, the volume of hydrogen and other gases in the ingot is reduced to a low level. As a result large press forgings now can be forged from sounder, tougher and cleaner ingots with the possibility of flaking or microcracking practically eliminated.

In Bethlehem Steel Co.'s vacuum pouring process, steel melted in the electric furnace is poured either into a pony ladle at the top of the vacuum pouring unit and then into an ingot mold, or from the furnace ladle into a second ladle contained in the vacuum tank. Steel flows from the pony ladle or the furnace ladle through a high vacuum in the degassing chamber. The flow is actually spray in contrast to the tight rope-like stream of the air cast ingot. The disintegration of the hot metal into small droplets releases the hydrogen as well as other gases.

While the processing and subsequent heat treating of forgings may reduce hydrogen in the exterior portions of the air cast ingot, the interior content remains at high level. However, in vacuum cast steels the low hydrogen content is found throughout the ingot cross section. Besides virtually eliminating flaking or microcracks, the removal of hydrogen in the vacuum pour greatly minimizes embrittlement tendencies in larger forgings.

Inspection and testing of the product is necessary, and one of the most important tests is the ultrasonic test which makes it possible to thoroughly examine the forging for internal soundness.

Metallurgical inspection procedures are carefully followed throughout all stages of manufacture, for detailed inspection is a necessity to insure the satisfactory performance required of forgings subject to severe service conditions.

The demand for press forgings, for severe service applications, made of vacuum cast steel has necessitated the doubling in size of Bethlehem's installation. Two additional vacuum degassing chambers which have been installed are capable of producing 120-in. diameter ingots weighing 535,000 lb. In all Bethlehem operates five vacuum degassing chambers capable of servicing electric furnaces producing ingots from approximately seven to nearly 270 tons. It is believed that the installation is the largest of its kind in the world. ▲

Figure 1 — A 116-ton generator shaft was forged from a 120-in. diameter, 260-ton vacuum cast ingot.

Steel Rolls Used for Hot Strip Mill Table

DURING the past five years, The Badall Co., Inc., has supplied carbonitrided steel rolls for use on a hot strip mill runout table at the Granite City Steel Co. These rolls have given service comparable to cast-iron rolls in all instances, and significant improvements in some areas.

The rolls supplied by Badall are 10 and 12-in. diameter carbonitrided steel of tubular design. These hollow rolls have plugs in each end, and a steel shaft running through the center or, in some cases a stub shaft in each end.

In all the mill table uses 159 rolls. The first 80 rolls are the 10-in. rolls. They are fabricated from thick steel plate, and the shell is carbonitrided to maximum depth. The second portion of the table consists of 79, 12 x 90-in. rolls. The 10-in. rolls have an open grid between them which permits the water to flow freely to the pit. The 12-in. rolls have a solid plate which tends to carry the water along with the rolls, and hence remains in contact with the rolls longer.

The hot strip mill processes 0.064 to ½-in. gage hot rolled steel bands in widths from 24 to 74 in. Temperatures during this operation range between 1100 to 1700 F. Water spray is provided for quenching.

Carbonitrided steel rolls can be produced with higher and more uniform hardness than cast iron rolls. Steel has the advantage of a higher modulus of elasticity and greater resistance to impact. In addition, better heat transfer, better wear properties, better finishes and generally lower over-all cost can be obtained.

There are generally three possible causes of failure or difficulty lodged against steel rolls used in this type of application; wear, warpage and oxide pickup. To date there have been no failures from these causes and the rolls are still in service, showing only normal wear. As anticipated, wear of the steel roll is better than with the cast-iron roll.

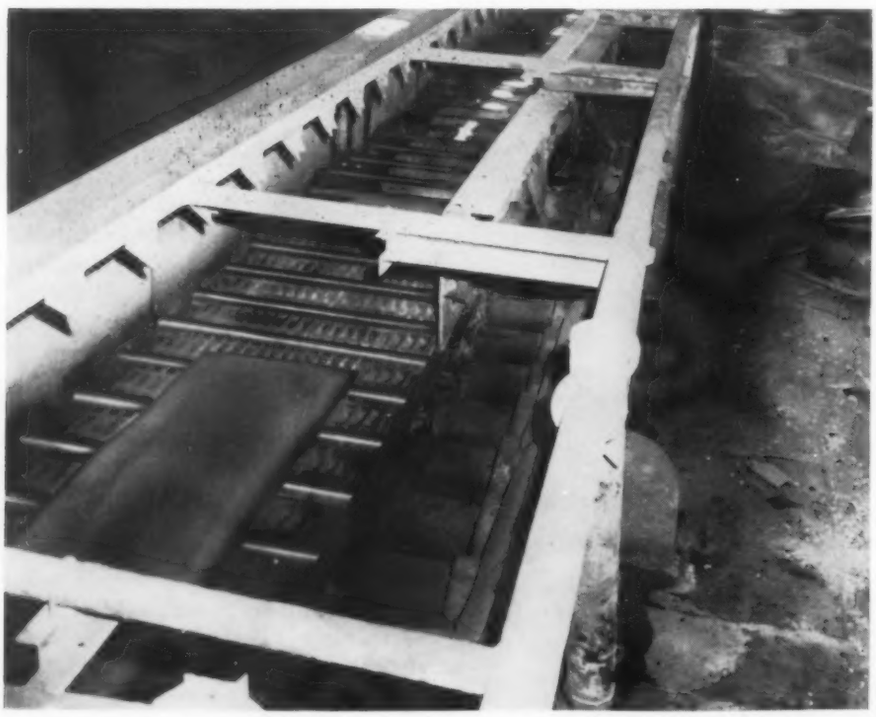
Oxide pickup on the steel roll, if sufficient, can actually make the roll surface rough enough to cause surface blemishes or flaws in the steel strip. This seems to be most common where the strip temperature is the highest. This problem has been eliminated by directing a continuous stream of water on the underside of the rolls. This was done on the first 13 rolls in this table. By keeping the temperature of these rolls at an approximate temperature of 150 F the scaling problem is eliminated.

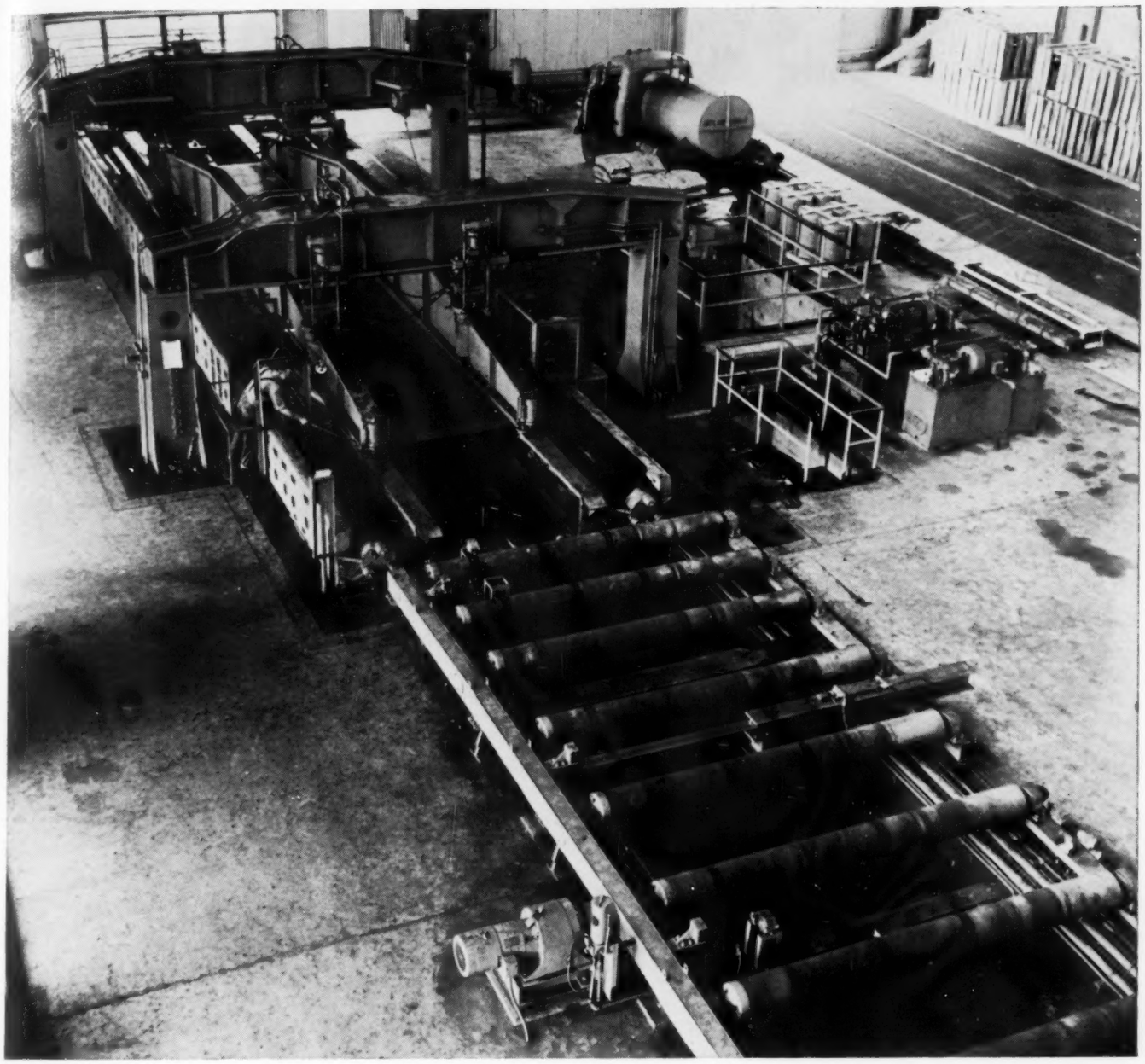
By way of comparison the prime cause of failure on the iron rolls seems to be breakage. The steel rolls minimize the breakage problem. The tendency to warp is about the same for both materials. The resistance to thermal shock which is a considerable factor in roll life, is much greater in the case of the carbonitrided steel than with cast iron.

Badall carbonitrided steel rolls are case hardened to 90 to 100 scleroscope, with a case depth of up to $\frac{3}{16}$ in. Roll necks are kept under 50 scleroscope. These rolls withstand heavy pressures and high loads and show high resistance to abrasion.

By the carbonitriding process, the wearing surface of these rolls is changed from a low carbon to a higher carbon content producing a surface of approximately the same physical properties as expensive tool steels. The careful control of temperatures, along with the keeping of the rolls in a vertical position during the carbonitriding and quenching operations, minimizes any distortion in the rolls. ▲

Figure 1 — Roll pickup has been reduced by cooling the underside of the rolls with a continuous water spray.





PLANING TIME ALMOST HALVED

New Birdsboro plate planer cuts on back stroke, positions, and ejects on forward stroke

■ Here's how this new Birdsboro planing equipment speeds production of large diameter welded pipe: On the forward stroke it brings a new plate into position and automatically ejects a finished plate. On the back stroke it cuts both sides, then repeats the cycle. The planer's advantages to its user include a virtual halving of planing time . . . allowing production of three miles of 18″ to 42″ O.D. pipe per *day*.

For details on this—and other—unusual mill machinery that delivers significant user benefits, write: *Sales Department, Engineering Department and Mfg. Plant:* Birdsboro, Pa., *District Office:* Pittsburgh, Pa.

MM1-61

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Continuous Slab Inspection Possible With Gamma Ray System

THE Rauland Corp., a subsidiary of Zenith Radio Corp., and Picker X-Ray Corp. announced a new gamma ray image intensifier system that detects minute flaws in four in. thick steel and other dense objects, and projects images of the flaws on a tv screen.

Used in conjunction with the Picker Orthicon Camera and Cyclops cobalt 60 unit, the new Rauland intensifier tube will permit an assembly line type of continuous inspection of dense materials which heretofore could be inspected only by gamma ray photographs, and of other materials which could not be inspected without destroying them.

Gamma rays produced by a dime-sized piece of cobalt 60 can penetrate dense materials better than room-sized X-ray machines. Their energy is so great that they could not produce a satisfactory image on a conventional fluoroscope. Consequently, their use in nondestructive testing has been limited to photography, a process far too slow and costly to permit assembly-line continuous inspection.

The new system suggests a number of potential uses in steel manufacture. In rolling mills when steel billets are formed into slabs, the ends of the red hot slabs are visually inspected for gas bubbles or pieces of slag. When flaws are found, the operator shears off about six in. of the slab, which is scrapped, and again inspects the slab end. He continues until no more defects are seen, a process which wastes time and a considerable amount of good steel. One mill has estimated that if it could save only one in. of good steel from each slab, its annual savings would be nearly $700,000.

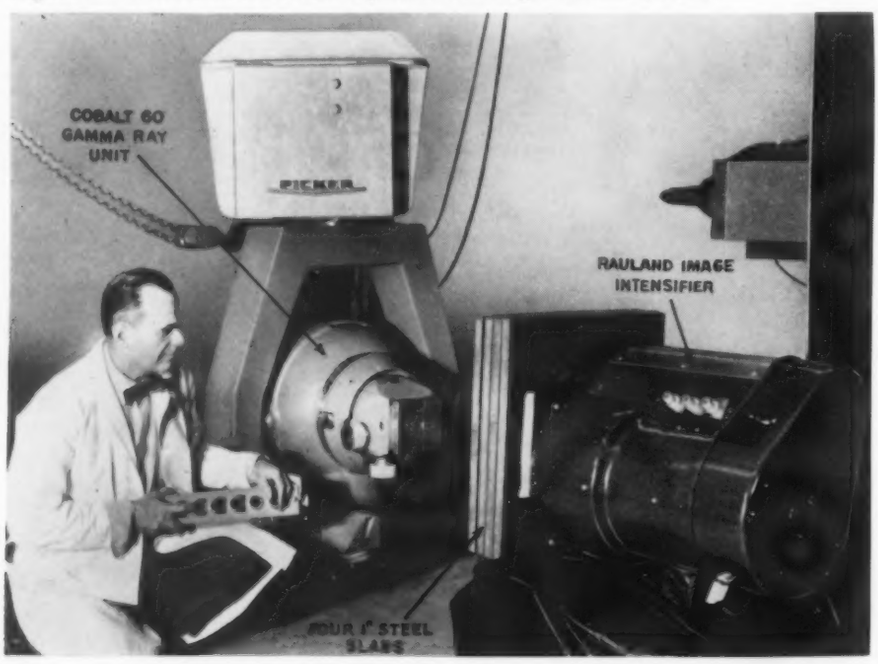
With the gamma ray image intensifier system, an operator sitting in his control room could watch on a tv screen the slabs of steel as they move along the tables, determine the exact location of each defect and shear off only as much steel as is necessary to cut off the flawed section. Experimental studies have indicated that this method of visual inspection can effect substantial economies. Development work on such a system is now in progress.

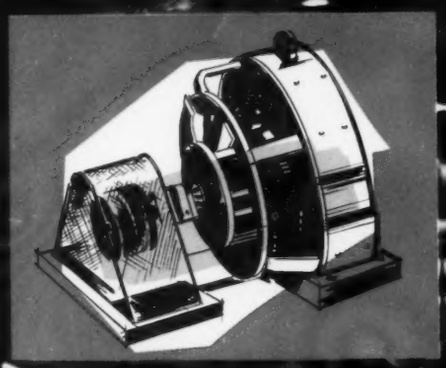
Other potential applications are for such purposes as inspection of castings and other metal objects that are too dense for X-ray study.

In operation, gamma rays from the cobalt 60 unit will be directed through the material being inspected to a thin metal plate at one end of the new Rauland tube. Here some of their energy is transferred to electrons of low enough intensity to produce a fluoroscopic image, which is intensified by the tube to produce a picture at the other end about 1000 times brighter, sufficient to provide a clear picture on a remote tv screen or to be viewed directly through an optical system. ▲

Figure 2 — A 1-in. steel disk, with ¼ and ½-in. diameter holes in it, was used as a test device to determine the detection efficiency of the inspection system.

Figure 1 — Detection of defects is possible through four in. of steel.





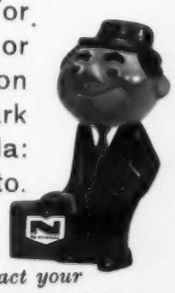
REYNOLDS METALS COMPANY KEEPS ALUMINUM PRODUCTION ROLLING WITH AN ASSIST FROM NATIONAL BRUSHES

TRADE-MARK

Reduction operations at the Corpus Christi Plant of Reynolds Metals Company produce a steady flow of basic aluminum on a round-the-clock schedule. Every component in the power plant must provide exacting performance and rugged reliability to meet production schedules.

"National" Brushes—used in the power generating section—are small but vital components that contribute to uninterrupted d.c. power supply for the aluminum pot lines. For many years these brushes have provided good commutation and life with minimum commutator maintenance.

To National Carbon Company, improved electrical operations mean a positive carbon brush service program. For details, call your "National" Brush Man or write National Carbon Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, N. Y. In Canada: Union Carbide Canada Limited, Toronto.



Contact your "National" Brush Man

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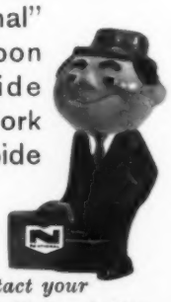
CONSOL COAL'S ELECTRIC SHOVELS MOVE TREMENDOUS TONNAGES WITH AN ASSIST FROM NATIONAL BRUSHES

TRADE MARK

Huge electric shovels take one tremendous bite after another at the eastern Ohio mines of the Hanna Coal Company, a division of Consolidation Coal Company. The swinging peak loads are extremely demanding on the shovels' electrical system–there is no room here for short cuts on quality.

"National" Brushes–small but vital components on such equipment–offer proved commutation and life under these swinging peak load conditions. A real contribution to sustained production with minimum maintenance.

National Carbon Company offers a positive service program to assist in solving any brush problems encountered today in all types of mining operations. To realize this assistance, just call your "National" Brush Man or write National Carbon Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, New York. In Canada: Union Carbide Canada Limited, Toronto.



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New Cranes Have Pressurized Walk-in Girders

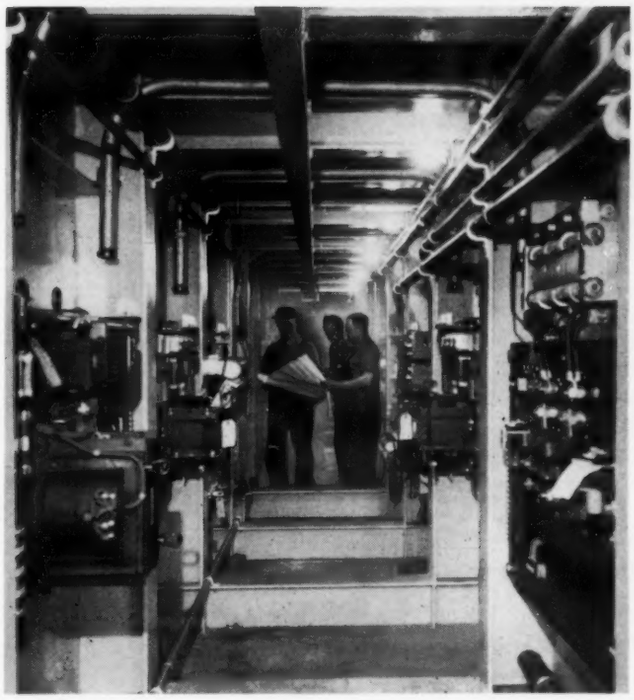

Figure 1 — Radical design change for overhead traveling cranes includes a pressurized and well-lighted passageway inside the main girder, running length of the crane. The area is utilized for electronic controls and power components.

OVERHEAD traveling cranes, used almost universally in large plants and foundries throughout the world, have just undergone one of their most radical design changes in their 74-year history. Details were revealed by Harnischfeger Corp. of Milwaukee, a pioneer in crane building who have built more than 25,000 units.

The new cranes are expected to have reduced original costs and about 75 per cent less maintenance.

The first two units recently were installed at a large cement plant in Kansas.

Others already are ordered and are in final stages of engineering at Harnischfeger's main plant in Milwaukee.

On the surface, the most obvious change is that the interior of the main girder is utilized as a corridor in which are located strategic controls and power components, and inside which maintenance crews can conveniently work. These interior aisles of the two Kansas cranes are 8 ft high, 5 ft wide and extend almost the full length of the 120-ft girders.

Figure 2 — First installation of two initial walk-ins are at a large Kansas cement plant. Each crane averages a 15-ton lift every 53 sec for 16 hr per day.

The hollow-beam feature (borrowed from a European development) provides in itself a certain degree of protection for the electronic controls and other components. However, for more realistic protection against outside atmospheres in which the cranes often must work, each aisle or passageway is pressurized similar to the cabin of an airliner.

This pressurization is accomplished by a relatively small but powerful blower which forces air continually into the girder, after screening it through wool-bag filters which automatically clean themselves. A pressure of about 2 psi gage is maintained—ample to prevent dust seepage and at the same time protecting against excessive heat accumulation from components within the girder.

In addition to coping with high concentrations of abrasive dust at cement mills, this same pressurized walk-in arrangement will be equally valuable with a wide range of other heretofore difficult conditions where

atmosphere plays havoc with electrical relays, contactors and other sensitive components.

The job of high-girder inspection and maintenance is simplified by the new configuration.

To make this work readily accessible and even more economical, all electrical panels and control equipment are mounted against the interior walls.

Still another ingenious touch is in the form of a small but heavy-capacity P&H electric hoist suspended from an I-beam "track" which runs the full length of the ceiling inside the girder. The traveling hoist is used for easy handling of any heavy equipment inside the girder, or to elevate tools through a dust-proof hatch from the main floor 80 ft below.

Half the economy of the new design is a result of being able to eliminate "auxiliary gingerbread."

With the new walk-in design, four individual motors can be easily spotted at the four corners and geared directly to the wheels—thus eliminating the long cross-shafts as well as most of the other mechanical linkage.

An advanced control system is incorporated in the two Kansas cement units.

The cranes have a newly developed bucket-control system which Harnischfeger calls an "adjustable voltage d-c electronic stepless control."

By using variations of this "electronic stepless control" (everything except the bucket hoists are a-c powered), all eight motions of the crane and bucket are governed by only two "joy stick" levers instead of the conventional four.

From a production standpoint, a beneficial result of the a-c electronic stepless control has proved to be faster operation and more exact load positioning.

These two walk-in cranes, with rated capacities of 15 tons each, are required to make 15-ton lifts (including bucket) on an average of every 53 sec—straight through two shifts for 16 hr per day.

Total amount of material handled is 540 tons per hr per crane. ▲

Allegheny Ludlum Investigates Cupola Operations

THE successful completion of a large-scale melting test in Europe, combining certain phases of the so-called direct reduction process with the basic hot blast cupola, was disclosed by Allegheny Ludlum Steel Corp.

The test made in a commercial conversion unit established conclusively that the direct reduction-hot blast cupola plant complex is an alternate route to molten metal direct from iron ore.

Allegheny Ludlum announced that they would continue exploration of this method with regard to flexibility and adaptability to given situations.

Among the considerations which make the process interesting is its flexibility. From a cold start, the hot blast cupola is capable of producing hot metal within four hr after start-up, and it can swing in three hr from 100 per cent R-N briquettes to 100 per cent scrap. The operator can thus take quick advantage of economically available materials.

Sulphur content of the hot metal can be as low as 0.007 per cent, or better than the blast furnace.

A 38.5-ton per hr cupola would be needed to supply Allegheny Ludlum with 800 tons of hot metal. Such an installation would produce hot metal for approximately $7 per annual ton capital cost for the cupola or $1,700,000.

In the process, advantage could be taken of low grade ores and blast furnace coke grades.

The test used 1100 tons of briquettes reduced from iron ore by the R-N process. The cupola successfully melted the 100 per cent briquette burden, establishing the capability of such a unit to achieve that result.

The test, sponsored jointly by Alleghney Ludlum Steel Corp. and the R-N Corp., took place recently at the Gusstahlwerk Witten A.G., Witten, Germany. The cupola there melted the 100 per cent briquette burden successfully with unit performance as to melting rates, etc., comparing favorably with the normal scrap burden used in the unit.

The molten iron resulting from the test was converted to ingots by both the open hearth and L-D basic oxygen processes under normal procedures.

Allegheny Ludlum has been investigating, during the past several years, various sources of molten iron for ingot production, with such investigation being directed to molten iron from iron ore by methods other than the standard blast furnace.

The one route in particular which appeared to offer promising possibilities anticipated the combining of certain phases of so-called direct reduction processes with the basic hot blast cupola. Such procedure involves a multi-stage method whereby the reduced iron ore product of the reduction step is converted to molten iron in the cupola.

Preliminary testing of this combination has so far primarily been confined to the R-N product and certain test programs which have been conducted jointly by the R-N Corp. and Allegheny Ludlum. The R-N reduction process involves reduction of the oxidic ores by the rotary kiln method in conjunction with a solid carbonaceous reductant. Following kiln reduction, the reduced material is beneficiated by magnetic separation and then compacted into a briquette having approximately 95 per cent contained iron with a metallization of 91 to 95 per cent.

The basic hot blast cupola has been developed to a high degree of operating efficiency and capability. Such a cupola operates on a blast preheat of 1000 to 1100 F with external water cooling of the shell which carries no internal lining except a small section of the shell below the tuyères. The unit taps continuously, with the melted iron being subjected to a high degree of refinement through reaction with a basic slag before leaving the iron tapping hole. The unit used has been in operation at the Gusstahlwerk Witten A.G. since 1954 converting a scrap burden to molten iron for ingot production by their L-D converter and basic open hearths. ▲

Here's a man who's ready to help you with a roll problem

But you don't need to have a roll problem to have a visit from Bill Curran, General Manager at National Roll. To the contrary, the "boss" spends a lot of his time with customers discussing their operations and roll requirements before problems have an opportunity to develop. This is typical of the personal interest National takes in helping customers get the benefits of maximum roll performance. For personal attention to *your* roll requirements, whether steel, iron or nodular iron, order from National. You'll see why . . . NATIONAL'S THE GROWING NAME IN ROLLS.

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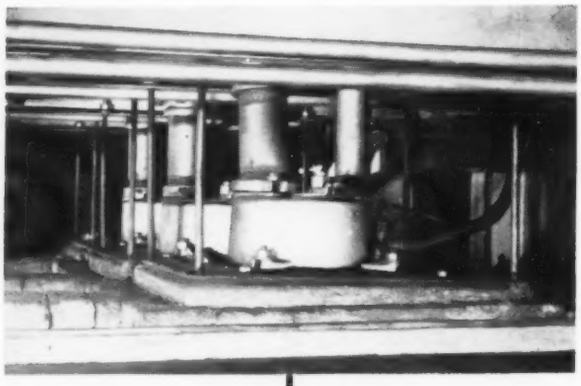
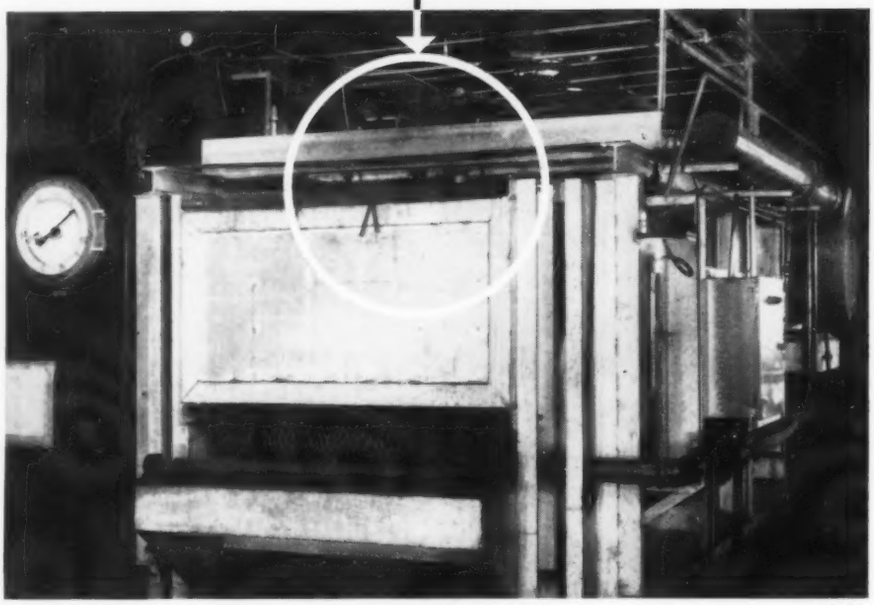
HAUCK helps speed production at FIRTH STERLING STEEL





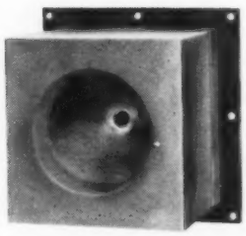
HC120

At Firth Sterling Steel, automated forging furnaces keep quality high and prices competitive. The modern bar steel furnace is geared for high speed—low cost production. Forming temperature over 2000°F must be maintained.

3 Hauck Radiant Cone Gas Burners supply the furnace heat. Roof mounted and automatically controlled they distribute uniform heat at a high rate of heat release and provide exceptional uniformity throughout the furnace. Specified because of their job proved ability to maintain proper temperatures under the heaviest work loads, Hauck gas burners deliver maximum heat outputs for minimum fuel inputs.

On the job at Firth Sterling for two years, the RCG burners have efficiently demonstrated their high performance ability. High speed heating has cut production time, reduced the formation of scale and improved the forgeability of the bars.

If quality control, low operating cost, sound combustion engineering counsel and on-the-spot field service have a place in your plans for new or changeover firing methods, Hauck Manufacturing Company can help you. Write for technical assistance and literature describing RCG burners and engineered combustion equipment.



Front view of RCG burner showing refractory cone surface for radiant heat, burner nozzles, angled opening for pilot flame and mounting plate.

HAUCK MANUFACTURING COMPANY

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SCHLOEMANN

Five-Tube Tester

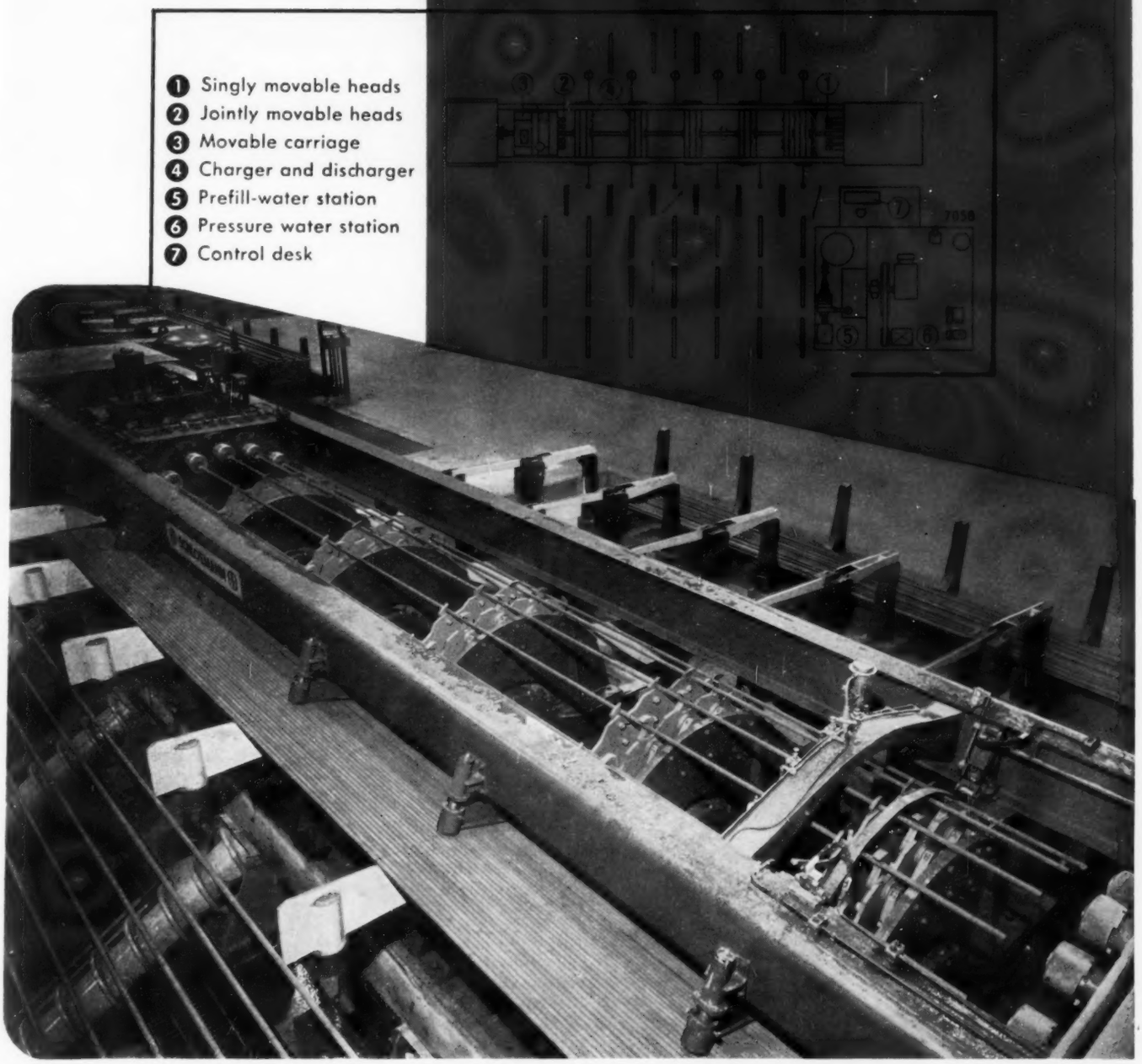

Photo: Courtesy of Jones & Laughlin Steel Corp.

A unique machine now in highly successful operation at the Aliquippa Works of Jones and Laughlin Steel Corporation is this SCHLOEMANN Five-Tube Tester. 1,200 tubes per hour or more can be tested hydrostatically, and sizes up to 50′ long, ½″ to 4″ in diameter can be handled. Automatic defective tube assorting device can be furnished. Only one operator needed. *For complete information send for leaflet 31 1e.*

SCHLOEMANN Tube Testers for the U.S.A. and Canada are manufactured by the AETNA-STANDARD Div. of Blaw-Knox Company.

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Date-line Diary...

April 1

Δ The AISI reported that steel production for the week ending April 1, 1961, totaled 1,632,000 net tons (about 57.3 per cent of capacity), compared with 1,611,000 tons one week ago (56.6 per cent of capacity) and 2,527,000 tons one year ago. Index of production was 87.6.

Δ The AISI estimated that $5,000,000,000 to $6,000,000,000 would be spent in 1961 to expand steelmaking facilities throughout the world. Expected improvements in the U. S. will total $1,200,000,000 while Russian improvements are expected to total $1,000,000,000.

Δ American Iron Ore Assn. and AISI joint report shows receipts of iron ore in the U. S. for February, 1961, totaled 2,448,136 gross tons compared with 4,430,906 tons in February, 1960. Consumption of iron ore in February, 1961, totaled 6,060,207 gross tons compared with 11,337,345 tons in February, 1960. Blast furnaces operating February 28, 1961, totaled 119 of the existing 256. On February 29, 1960, 231 blast furnaces were in operation.

April 4

Δ The Bureau of Mines reports that domestic shipments of steel mill products in January, 1961, totaled 4,600,000 tons compared with 4,000,000 tons in December, 1960. Imports of steel mill products totaled 145,000 tons and exports totaled 132,000 tons in January, 1961.

Δ Phoenix Steel Corp. reported 1960 sales of $37,781,532, net lost of $1,962,089, compared with 1959 sales of $60,615,789, net income of $2,108,754, equal to $2.03 per share.

Δ Assemblies of U. S. built automobiles in the first quarter of 1961 totaled 1,184,722, the lowest number for a similar period since 1952.

April 5

Δ The Labor Dept. reported that unemployment fell by 210,000 in the month ended March 15, less than seasonal amount, to a total of 5,495,000. Employment rose 816,000 in the same period to a total of 65,516,000.

Δ The AISI reported that lost time injuries per million man-hr, in the steel industry fell to a record low of 3.14, down from 3.51 in 1959. Severity (days lost per million man-hr) dropped to 742 compared with 915 in 1959.

Δ The Bureau of the Census reported that shipments of iron and steel castings in 1960 totaled 13,806,597 tons compared with 14,637,188 tons in1959.

Δ The Bureau of Mines reports that consumption of scrap in February, 1961, totaled 3,930,000 gross tons compared with 4,059,361 tons in January, 1961; consumption of pig iron in February, 1961, totaled 3,614,000 gross tons compared with 3,682,210 tons in January, 1961.

Δ The Bureau of Mines reports that production of Pennsylvania anthracite in March, 1961, totaled 1,463,000 tons compared with 1,756,000 tons in February, 1961, and 1,680,000 tons in March, 1960.

April 6

Δ Bethlehem Steel Corp. announced that two additional open hearths will be put into operation at Sparrows Point, raising the number working to 28 of the 35 available furnaces.

April 7

Δ Inventories of U. S. built cars totaled 935,500 as of April 1, 1961, compared with 1,021,000 cars as of March 1, 1961, and 1,020,000 as of April 1, 1960.

April 8

Δ The AISI reported that steel production for the week ending April 8, 1961, totaled 1,696,000 net tons (59.5 per cent of capacity), compared with 1,632,000 tons one week ago (57.3 per cent of capacity) and 2,417,000 tons one year ago. Index of production was 91.0.

April 10

Δ The AISI reported that shipments of finished steel mill products totaled 4,250,720 net tons in February, 1961, compared with 4,600,000 tons in January, 1961, and 7,600,000 tons in February, 1960.

Δ The Aluminum Assn. reports that shipments of aluminum sheet and plate in February, 1961, totaled 106,273,000 lb, compared with 109,135,000 lb in February, 1960 and 115,181,000 in January, 1961. Shipments of aluminum foil in February, 1961, totaled 18,835,224 lb compared with 19,099,732 lb in February, 1960.

Δ Jessop Steel Co. reported 1960 net income of $756,776, equal to $1.11 per share compared with 1959 net income of $1,870,354, equal to $2.90 per share. These figures do not include the results of operation of Green River Steel Corp.

Δ Alcoa announced a five per cent reduction in the price of its rigid conduit.

Δ Carpenter Steel Co. announced a ten per cent reduction in the basic price of its type 430 stainless steel bars, billets and wire.

April 11

Δ The AISI reports that the steel industry's payroll for hourly and salaried workers in February, 1961, totaled $267,052,252, compared with $274,874,275 in January, 1961. Total employed numbered 484,286 in February compared with 477,543 in January. Payroll cost per hour worked by hourly employees was $3.462 in February, compared with $3.469 in January, not including 47.1¢ supplemental employee benefits. Average hours per week worked were 35.9 in February, 1961, compared with 34.0 in January, 1961.

Δ The Bureau of the Census reports that shipments of commercial steel forgings in February, 1961, totaled 89,272 tons compared with 95,077 tons in January, 1961, and 129,799 tons in February, 1960.

Δ The Bureau of Statistics reports that Canadian steel production in March, 1961, totaled 556,855 tons compared with 585,922 tons in March, 1960. First quarter of 1961 production totaled 1,471,969 tons compared with 1,692,794 tons in the first quarter of 1960.

Δ The Dow-Jones industrial average rose 8.38 to a new record of 692.06.

Δ The Commerce Dept. reported that retail sales volume, seasonally adjusted, in March, 1961, climbed to $18,100,000,000, one per cent above February, 1961, sales.

April 12

Δ The Labor Dept. reported that the average factory work week in March, 1961, was 39.3 hr, compared with 39.1 hr in February, 1961. Average weekly paychecks in March were $90.71 compared with $89.86 in February.

Δ The Senate Labor Committee has approved minimum wage legislation designed to gradually increase the minimum wage to $1.25 per hr and extend coverage to include 4,000,000 more people.

April 13

Δ The Bureau of the Census reported that net shipments of aluminum pig and ingot in February, 1961, totaled 116,851,000 lb compared with 100,309,000 lb in January, 1961, and 170,692,000 lb in February, 1960. Shipments of aluminum mill products totaled 231,916,000 lb in February, 1961, compared with 241,309,000 lb in January, 1961, and 256,127,000 lb in February, 1960.

Δ A Federal grand jury indicted General Motors Corp. of attempting to monopolize the diesel locomotive manufacturing industry.

Δ A Federal Trade Commission examiner ruled that Luria Brothers and Co., Inc., illegally restrained competition in the iron and steel scrap industry.

Δ The Bureau of the Census reported that 1960 shipments of commercial steel forgings totaled 1,268,178 tons compared with 1,373,801 tons in 1959. Unfilled orders at the end of December, 1960, totaled 268,217 tons compared with 420,118 tons at the end of December, 1959.

April 14

Δ The Commerce Dept. reported that imports of steel in February, 1961, totaled 152,000 tons, compared with 145,000 tons in January, 1961, and 468,000 tons in February, 1960. Sales of steel to foreign customers in February, 1961, totaled 147,000 tons, an increase of 15,000 tons over January, 1961, but 20,000 tons below February, 1960. Exports in February, 1961, were valued at $31,600,000, imports $20,900,000, as valued at foreign ports.

Δ Prices of railroad steel scrap averaged $1.50 to $2 a ton less than March sales with No. 1 railroad heavy melting scrap at $43.12 ton.

Δ The AISI reported that total profit of the nation's steel companies dropped to $801,736,691 in 1960, compared with $830,605,769 in 1959. Total revenues in 1960 amounted to $14,100,000,000 compared with $14,200,000,000 in 1959. Profit margin in 1960 averaged 5.7 per cent compared with 5.8 per cent in 1959. Employment cost in 1960 totaled $5,500,000,000, up 6.7 per cent from $5,100,000,000 in 1959. Taxes paid in 1960 totaled $239,000,000. Money available for reinvestment in 1960 totaled $239,500,000 compared with 277,200,000 in 1959.

April 15

Δ The AISI reported that steel production for the week ending April 15, 1961, totaled 1,748,000 net tons (about 61.4 per cent of capacity), compared with 1,696,000 tons one week ago (59.5 per cent of capacity) and 2,225,000 tons one year ago. Index of production was 93.8.

April 17

Δ Government figures showed that personal income in March, 1961, ran at a seasonally adjusted annual rate of $409,600,000,000, up $3,400,000,000 over February, 1961.

Δ Bethlehem Steel noted that effective May 2, the conversion price of common stock will increase to $38.75, payable by surrender of $25 in debentures and $13.75 in cash, compared with present $37.50 a share, surrender of $25 in debentures and $12.50 in cash.

April 18

Δ The Dept. of Commerce reported that production and shipments of titanium mill products in February, 1961, totaled 1,183,933 lb, compared with 982,934 lb in January, 1961, and 497,701 lb in February, 1960.

Δ The ARCI reported that deliveries of new freight cars in March, 1961, totaled 3874, compared with 1958 in February, 1961, and 5950 in March, 1960. Orders in March, 1961, totaled 1796, compared with 1536 in February, 1961, and 1957 in March, 1960. Backlog of cars on order as of April 1, 1961, totaled 15,801, compared with 18,429 on March 1, 1961, and 42,131 on April 1, 1960.

Δ Can Manufacturers Institute, Inc., reports that steel consumed by the can industry in February, 1961, totaled 290,839 tons, an increase of 0.7 per cent over February, 1960.

Δ Lone Star Steel Co. reported that the proposal of the Equitable Life Assurance Society covering a loan of $40,000,000 has been accepted. The funds will be used to pay off a government loan and for expansion of existing facilities.

April 19

Δ Morgan Stanley nationwide underwriting group offered $300,000,000 United States Steel Corp. 4½ per cent sinking fund debentures due 1986 at 99¼ per cent to yield 4.55 per cent.

April 20

Δ United States Steel Corp. cut price of type 410 stainless steel bars, rods, cold-finished wire and forging billets 10 per cent.

Δ The Dept. of Commerce reports that shipments of iron and steel castings in January, 1961, totaled 914,043 tons, compared with 914,224 tons in December, 1960, and 1,341,559 tons in January, 1960.

April 21

Δ The Aluminum Assn. reports production of primary aluminum in the first quarter of 1961 totaled 452,009 tons compared with 491,538 tons in the same period, 1960. Production in March, 1961, totaled 152,022 tons compared with 138,560 tons in February, 1961.

Δ Lone Star Steel Co. reports for the year 1960, sales totaling $55,213,000, net income amounting to $2,348,000, equal to 60¢ per share, compared with 1959 sales totaling $112,944,000, net income of $14,176,000 or $3.61 per share.

Δ The Dept. of Commerce reports that shipments of nonferrous castings in February, 1961, totaled 153,246,000 lb, compared with 165,876,000 lb in January, 1961.

April 22

Δ The AISI reported that steel production for the week ending April 22, 1961, totaled 1,784,000 net tons (about 62.6 per cent of capacity) compared with 1,748,000 tons one week ago (61.4 per cent of capacity) and 2,238,000 tons one year ago. Index of production for the week was 95.8.

April 27

Δ The National Machine Tool Builders Assn. reports that net new orders of cutting and forming type ma-

Steel Companies Quarterly Financial Reports—Quarter Ending March 31, 1961

	Period	1961 Net Sales	1961 Net Profits	1961 Earnings per share	1960 Net Sales	1960 Net Profits	1960 Earnings per share
Acme Steel Co.	1st quar.	$ 30,663,748	$ 27,365	$	$ 46,851,347	$ 2,092,522	$0.72
Alan Wood Steel Co.	1st quar.	13,263,700	(225,762)	(0.41)	20,205,658	854,995	1.14
Allegheny Ludlum Steel Corp.	1st quar.	54,185,543	1,432,228	0.37	79,672,618	4,791,584	1.24
Armco Steel Corp.	1st quar.	187,571,507	9,260,646	0.63	274,308,574	23,957,994	1.62
Bethlehem Steel Co.	1st quar.	433,450,071	7,971,692	0.14	655,821,014	51,828,727	1.10
Byers, A. M. Co.	1st quar.	9,302,895	168,000	0.19	12,916,610	132,700	0.14
Carpenter Steel Co.	1st quar.	17,142,676	946,328	0.50	23,059,439	1,839,428	0.98
The Colorado Fuel and Iron Corp.	1st quar.	...	(682,885)	(0.20)	...	2,846,692	0.72
Continental Steel Corp.	1st quar.	11,389,430	881,060	0.85	13,218,264	1,135,414	1.10
Copperweld Steel Co.	1st quar.	22,543,880	(95,061)	(0.08)	36,140,542	1,389,174	1.18
Crucible Steel Co. of America	1st quar.	40,391,000	(1,644,000)	...	71,634,000	2,725,000	0.67
Detroit Steel Corp.	1st quar.	15,988,107	(118,168)	(0.03)	34,671,918	3,539,607	0.90
Eastern Stainless Steel Corp.	1st quar.	15,031,316	473,903	0.33	18,430,511	779,335	0.54
Edgewater Steel Co.	1st quar.	3,671,087	66,029	...	4,579,704	163,264	...
Firth Sterling, Inc.	1st quar.	5,190,200	(234,600)	...	5,904,800	(179,900)	...
Granite City Steel Co.	1st quar.	31,124,284	1,910,275	0.44	43,423,656	4,313,655	1.00
Inland Steel Co.	1st quar.	160,947,733	8,143,592	0.46	227,565,809	18,743,934	1.07
Interlake Iron Corp.	1st quar.	17,743,809	308,306	0.14	27,828,679	1,862,848	0.83
Jessop Steel Co.	1st quar.	...	97,699	0.14	...	547,735	0.85
Jones & Laughlin Steel Corp.	1st quar.	158,106,000	2,587,000	0.28	254,424,000	17,794,000	2.22
Kaiser Steel Corp.	1st quar.	56,313,214	(1,063,441)	(0.57)	64,987,105	6,686,660	1.79
Keystone Steel & Wire Co.	1st quar.	26,406,433	1,288,720	0.69	34,535,998	2,212,339	1.18
	9 mo.	70,244,969	2,797,470	1.49	97,864,887	6,486,597	3.46
Lone Star Steel Co.	1st quar.	13,595,316	117,194	0.03	18,868,326	2,484,095	0.53
Lukens Steel Co.	1st quar.	21,155,207	541,365	0.57	30,416,889	2,314,442	2.43
McLouth Steel Corp.	1st quar.	39,987,171	2,175,975	0.58	63,320,447	5,826,974	1.61
National Steel Corp.	1st quar.	136,780,508	5,862,026	0.77	219,842,172	17,718,342	2.35
Phoenix Steel Corp.	1st quar.	9,816,000	(791,000)	(0.73)	17,203,000	123,465	0.11
Pittsburgh Coke & Chemical Co.	1st quar.	10,325,000	(434,000)	(0.46)	15,974,000	660,000	0.47
Pittsburgh Steel Co.	1st quar.	25,886,961	(1,246,956)	(0.99)	50,623,846	2,167,577	1.16
Republic Steel Corp.	1st quar.	196,759,205	5,822,521	0.37	375,578,202	28,239,545	1.80
Sharon Steel Corp.	1st quar.	20,573,724	(550,763)	(0.50)	47,502,932	2,057,249	1.86
Steel Co. of Canada, Ltd.	1st quar.	63,742,357	4,588,672	1.06	82,961,125	8,197,125	1.89
United States Steel Corp.	1st quar.	708,712,707	31,976,670	0.47	1,187,554,615	112,578,752	1.97
Universal Cyclops Steel Corp.	1st quar.	...	598,058	0.31	...	2,085,994	1.08
Vanadium-Alloys Steel	1st quar.	6,288,528	277,679	0.43	8,164,861	627,733	1.01
	9 mo.	17,319,201	656,137	1.02	23,103,778	1,884,665	3.02
Wheeling Steel Corp.	1st quar.	44,970,000	(410,000)	...	77,122,000	5,547,000	2.43
Youngstown Sheet and Tube Co.	1st quar.	118,676,245	2,679,425	0.77	198,026,004	12,891,248	3.70
Washington Steel Co.	1st quar.	...	250,098	0.38	...	737,642	1.15
	6 mo.	...	494,935	0.75	...	1,398,492	2.18

Figures in parentheses denote loss.

chine tools in March, 1961, amounted to $69,550,000 compared with $46,400,000 in February, 1961. Shipments of cutting and forming type machine tools in March, 1961, amounted to $55,000,000 compared with $45,650,000 in February, 1961.

April 28

Δ F. W. Dodge Corp. reports total construction contracts in March, 1961, equalled $3,165,816,000 compared with $3,046,345,000 in March, 1960. March, 1961, index (1947–1949 = 100) was 262, compared with February, 1961, at 239 and March, 1960, at 252.

Δ Westinghouse Electric Corp. reported 1961 first quarter sales of $436,103,000, net income of $9,067,000 equal to 25¢ per share, compared with first quarter of 1960 sales of $458,817,000, net income of $19,496,000 equal to 55¢ per share.

Δ The AISC reported that shipments of fabricated structural steel in March, 1961, totaled 292,361 tons compared with 260,158 tons in February, 1961, and 311,557 tons in March, 1960. Bookings in March, 1961, totaled 295,739 tons compared with 256,868 tons in February, 1961, and 383,409 tons in March, 1960. Backlog as of March 31, 1961, was 2,392,099 tons. All figures have been revised by the AISC to conform with the 1958 Census of Manufacturers.

Δ Allis-Chalmers Manufacturing Co. reported 1961 first quarter sales of $119,600,000, net income of $1,479,319 equal to 15¢ per share compared with 1960 first quarter sales of $127,384,042, net income of $2,645,273, equal to 28¢ per share.

Δ Harbison-Walker Refractories Co. announced a $7 per 1000 price reduction on high-duty and semisilica 9-in. brick and 9-in. sizes effective April 24, 1961. Special shapes were not affected.

Δ The Bureau of the Census reports that shipments of copper-base mill and foundry products in the fourth quarter of 1960 totaled 1,043,000,000 lb (metal weight) compared with 1,146,000,000 lb in the fourth quarter, 1959: shipments for the year 1960 totaled 4,298,000,000 lb, compared with 4,813,000,000 lb in 1959.

Δ American Iron Ore Assn. and AISI joint report shows receipts of iron ore in the United States for March, 1961, amounted to 2,896,557 gross tons, compared with 4,299,285 in March, 1960. Consumption in March, totaled 6,953,222 tons, compared with 11,788,224 tons in March, 1960. Blast furnaces in operation on March 31, 1961, totaled 124 of 255. On March 31, 1960, 223 blast furnaces were in operation.

April 29

Δ The AISI reported that steel production for the week ending April 29, 1961, totaled 1,858,000 net tons (about 65.2 per cent of capacity), compared with 1,784,000 tons one week ago (62.6 per cent of capacity) and 2,210,000 tons one year ago. Index of production was 99.7.

To Meet Customer Demands

New Side Trimming Line Installed In Tin Mill Will Improve Production Of Tinplate In Coils

Installation Called Most Modern Of Type In Industry

A new side trimming line to facilitate the production of tinplate in coils in Weirton Steel's Tin Mill Department was placed in operation recently.

W. H. Wright, Vice President and Chief Engineer, said the new installation, rated among the most modern pieces of equipment in the steel industry, was installed because of the increasing demand from customers for tinplate in coil form. The company will also continue to ship tinplate in the conventional cut sheets.

The new side trimming line, which began operating last month, and a second line, installed on an emergency basis, are used to trim the sides of the sheet steel before it is plated with tin, so it can be wound into coils and be ready for shipment as it comes off the tinning lines.

Mr. Wright explained that Weirton Steel's No. 4 and No. 5 tinplating lines have been equipped with edge control reels which insure that each coil is wrapped with a straight edge. This is necessary to prevent damage to the edges in bundling and shipping and also because straight edges are required when the coils are processed further by Weirton Steel customers.

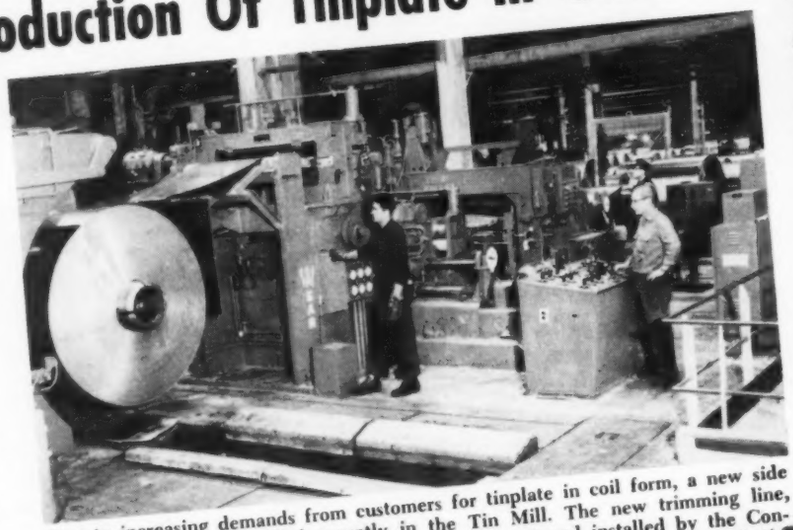
Mr. Wright also reported the installation of a new bundling line, which began operating about three months before the new side trimmer. The bundling line utilizes machinery to wrap coils in heavy paper and fasten them with steel straps. Formerly, this was a hand operation.

The side trimming operation takes place after the steel has been tempered to customer specification by the skin mills and before it is plated with tin. This process eliminates the waste which formerly resulted when the side trimming was done on the cutting lines, after the tinplating process.

The No. 2 side trimming line has a maximum speed of 4,000 feet per minute while the No. 1 line operates at a speed of 1,200 feet per minute. The No. 2 line is able to handle 30-ton coils 85 inches in diameter and 45 inches wide. The line also is equipped with a mash welder, a relatively new operation which provides a smoother weld that does not damage other sections of the coil as it is wound.

All of the new facilities were designed by the Weirton Steel Engineering Department and installed by the company's Construction Department.

Reprinted from Employees Bulletin, Weirton Steel Company, February, 1960



Due to increasing demands from customers for tinplate in coil form, a new side trimming line was installed recently in the Tin Mill. The new trimming line, designed by Weirton Steel's Engineering Department and installed by the Construction D[illegible] the [illegible] of sheet steel bef[illegible]ted with ti[illegible]

Once again—

proof that GPE Controls is the Steel Industry's "Partner in Progress"

The tin mill side trimming line at Weirton Steel Company, Division of National Steel Corp., was furnished by Wean Engineering Co., and equipped with the industry's most modern edge guide equipment—designed and built by GPE Controls, Inc.

Only GPE Controls offers steel mill edge guides with . . .

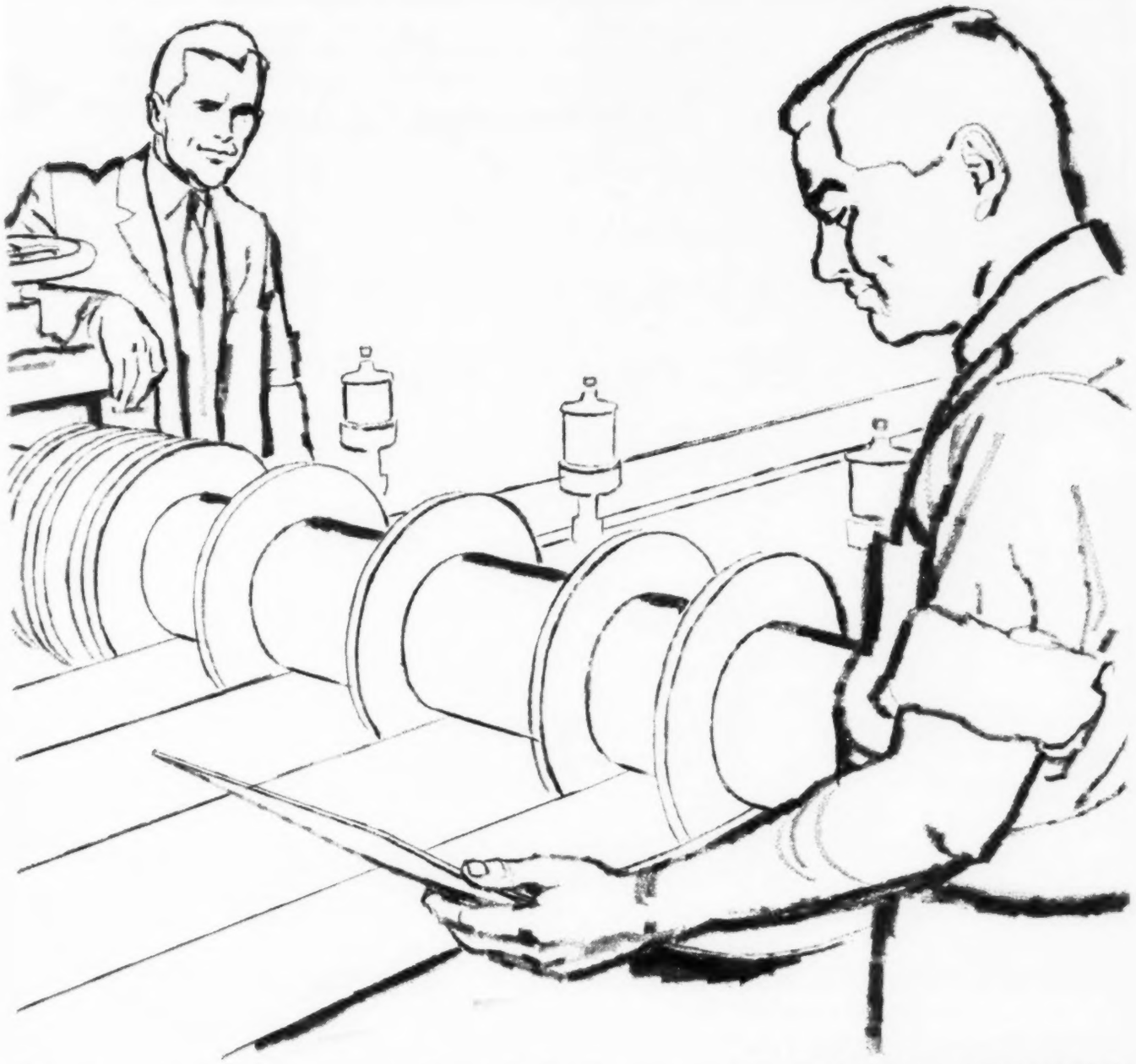
- ★ **Non-clogging sensing nozzles with lowest air consumption.**
- ★ **Unlimited force output with cylinder pressures to 2000 p.s.i., flows to 140 g.p.m and higher.**
- ★ **Variable-gain booster for simple screwdriver job-site matching of control system to speed, coil weight, etc.**

Write for NEW Bulletin EG84, which tells all about GPE Controls web guiding systems—and be sure that GPE Controls are specified and furnished on your next strip and tin mill installation.

GPE Controls Model 300 Edge Control, as furnished to Weirton Steel Company.

GPE Controls, Inc.
240 East Ontario Street
Chicago 11, Illinois

GPE Controls



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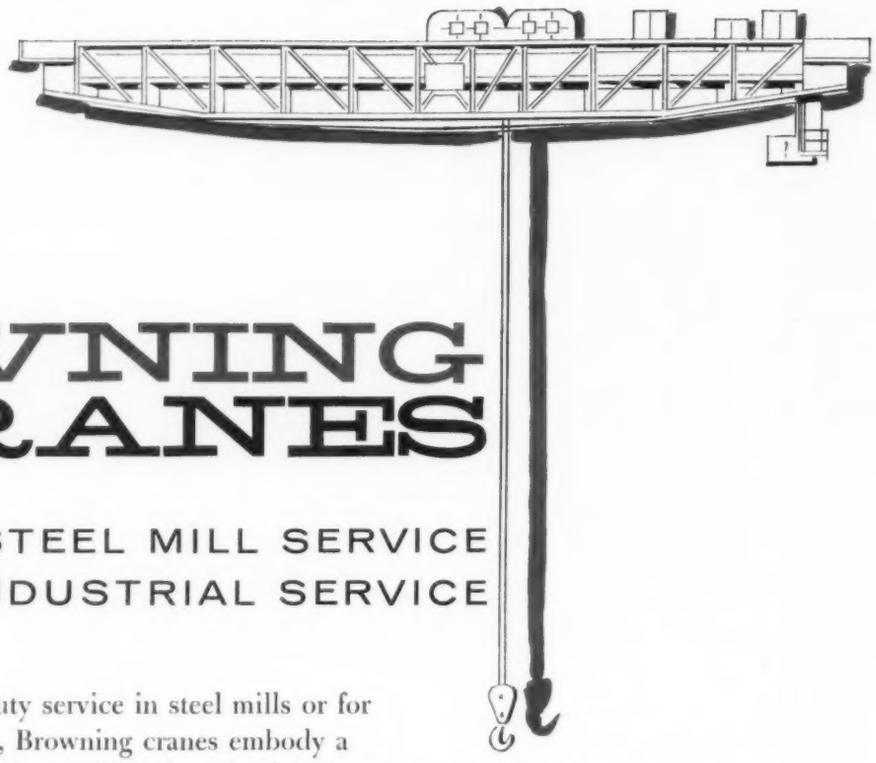

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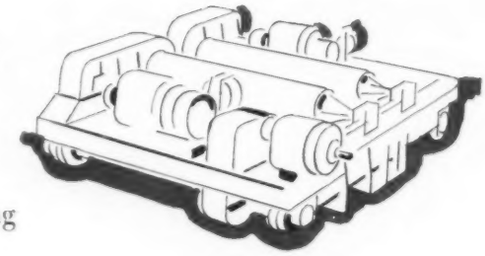

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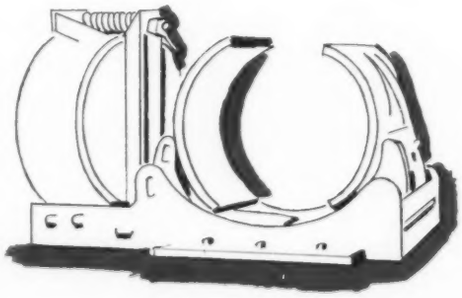

VICTOR R. BROWNING & COMPANY, INC.

WILLOUGHBY (CLEVELAND), OHIO

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Looking into one of the four soaking pits showing all RAMTITE products

Visitors' eye view of a RAMTITE Cover for one of the four new soaking pits

A large Eastern steel mill recently installed RAMTITE products in four soaking pits as a part of their new overall soaking pit program. A complete SPECIAL SUPER RAMTITE No. 25 anchored construction was installed in all covers, copings, walls and cored division walls. The slag lines of all walls in the four pits were of anchored 90-RAM high alumina plastic construction.

Have you refractory needs now which RAMTITE products could satisfy — or refractory problems which they may solve?

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Attn. Mr._____ Title_____

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National rewinds steel mill motor during vacation shutdown ...completes job with 1 day to spare

"Thanks for a job well done" reported the customer after National Electric Coil completed this major motor rewinding a day ahead of schedule.

The timetable was very tight, as the 3500 H. P. unit drives the main reversing mill. All work had to be accomplished during a planned mill shutdown, with time allowed after installation for acceptance tests.

National's preplanning took into account the following unusual operations:

- Top half of the field frame had to be unbolted and slid over to one side as there was no crane at the location adequate in capacity to lift the frame.
- The armature, while in its own bearings, was stripped, cleaned, and rewound with NECCOBOND coils – all coils and winding supplies having been manufactured in advance to expedite installation.
- A special gear and brake were fabricated to permit turning the armature during installation.
- The commutator was turned and undercut and the armature banded before final reassembly of the motor.

For a "well-done" job on your rotating electric machinery rebuilding or service needs, contact National Electric Coil. Our service is fast, thorough and dependable. Call National's Columbus plant, HUdson 8-1151, or check the nearest National field engineer.

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DIVISION OF McGRAW EDISON

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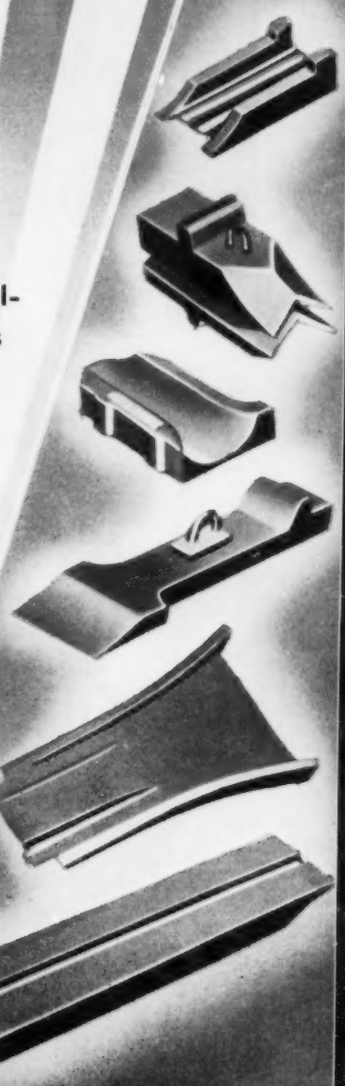
Join the many satisfied users of "TRANTINYL."



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STRAIGHTENING MACHINE GUIDES

HEAT RESISTING CASTINGS

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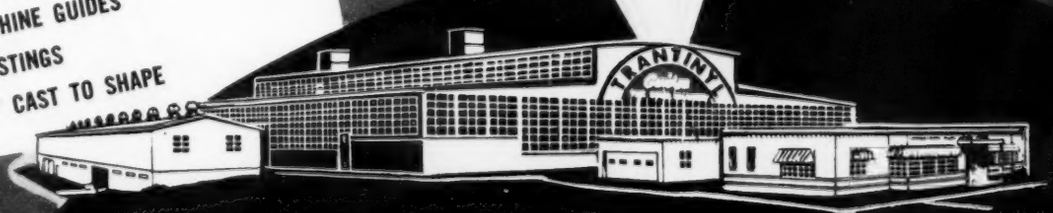
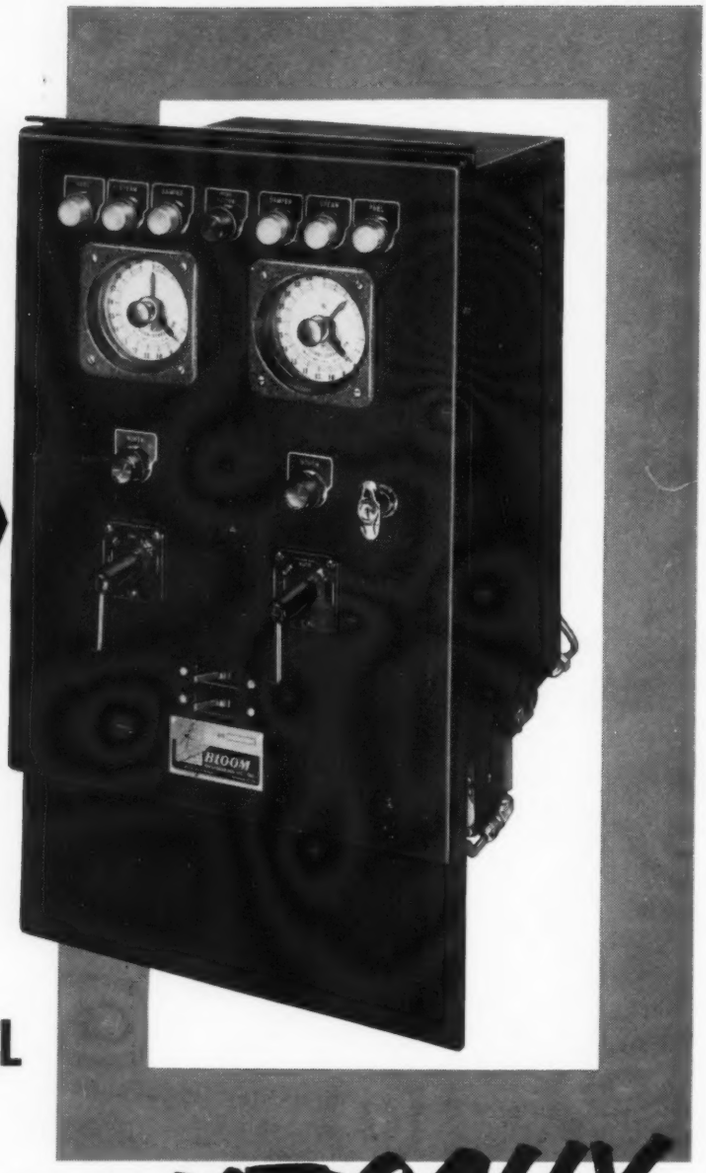


Youngstown Alloy Casting Corporation

Youngstown, Ohio

The BLOOM Time-Cycle Reversal Unit



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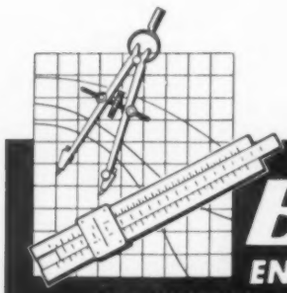
This complete, compact, factory-tested unit provides a combination electric-pneumatic system for Open Hearth Furnace, Soaking Pit and Glass Tank reversal. It eliminates reversal puffing and shortens reversal period. (10 to 15 seconds easily accomplished.)

Shorter reversal cycle improves furnace life.

These units have been in continuous service for eleven years. Trouble-free maintenance.



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WRITE or phone for complete information on the Bloom Time-Cycle Reversal Unit.

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EXAMPLE:
a process gas compressor

This is a single-stage H-line compressor, with open radial impeller. Casing diameter, 34 inches; total weight, 1020 pounds, capacity 3000 icfm. A **conventional** centrifugal to do the same job would be a 3-stage unit weighing about 9000 pounds.

Because corrosive gases will be handled, outer casing and all internal parts are made of stainless steels. This is economically feasible with Elliott H-line compressors due to their extremely small size and resulting light weight.

The one-piece, radial-bladed impeller has no cover or shroud member to create bending and hoop stresses.

Elliott H-line compressors include a wide variety of sizes and capacities, from 300 to 40,000 icfm.

The dependability of these compressors is proved by many years of operating experience with thousands of Elliott machines of similar design.

For specific information, call your Elliott district office, or write Compressor Department, Elliott Company, Jeannette, Pennsylvania.

ELLIOTT THE MOST COMPLETE LINE OF **INTEGRATED COMPRESSOR & DRIVER UNITS** 500 cfm to 600,000 cfm

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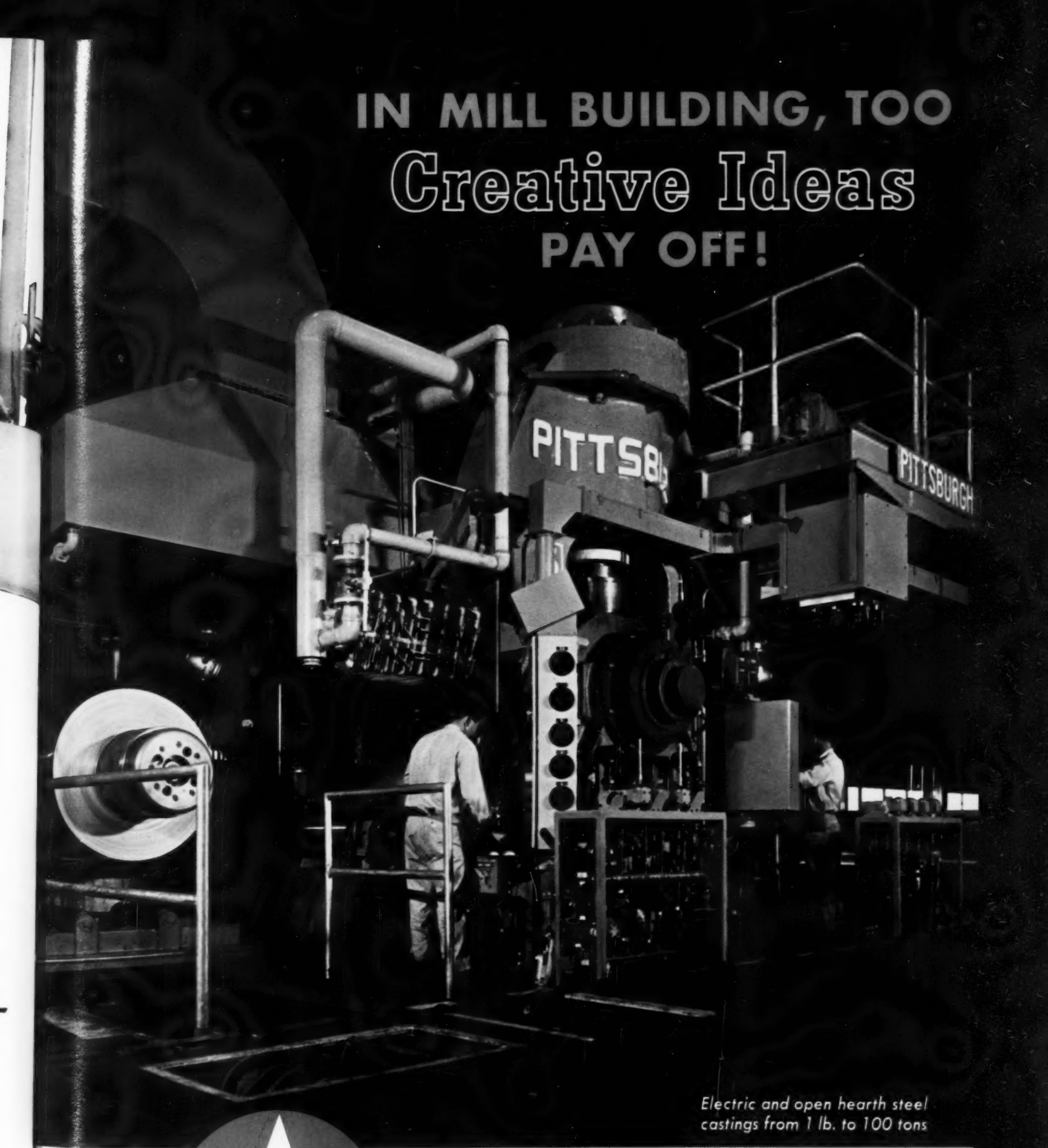

Electric and open hearth steel castings from 1 lb. to 100 tons

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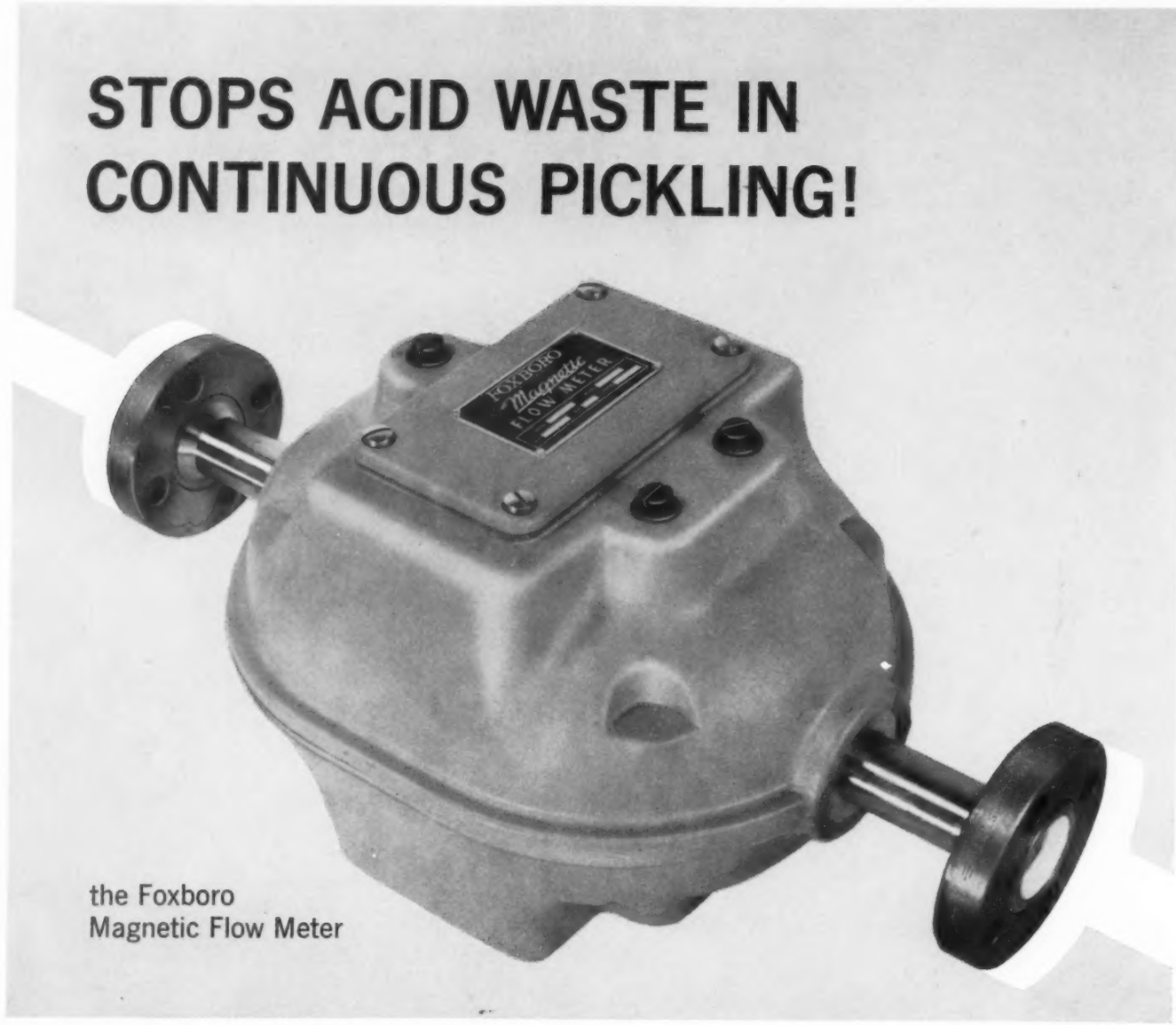


the Foxboro
Magnetic Flow Meter

Precise, accurate ratioing of acid-to-water for continuous pickling lines—with no acid wasted. That's the type of control you'll get with a Foxboro Magnetic Flow Meter as the heart of your ratio control system.

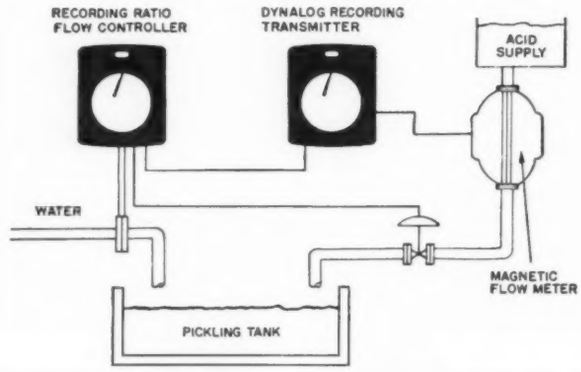
Measuring flow of acids and other corrosive liquids is no problem for the Magnetic Flow Meter. This meter has no orifice plate, no pressure taps—no line restrictions of any kind. There's nothing to corrode—nothing to take apart and clean. The meter connects by electric cable to a remote Foxboro Dynalog* Electronic Recorder.

Magnetic Flow Meters install as simply as a length of pipe—operate continuously with an over-all system accuracy of ±1%. Water-acid ratios stay right where you set them. Best of all, waste of acid is completely eliminated.

Ask your nearby Foxboro Field Engineer about the Magnetic Flow Meter, or write today for Bulletin 20-14C, which contains full information. **The Foxboro Company, 585 Neponset Avenue, Foxboro, Mass.**

*Reg. U.S. Pat. Off.

Typical Water-Acid Ratio System
using a Foxboro Magnetic Flow Meter



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MAGNETIC FLOW METERS

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ALEMITE OIL-MIST WITH THERMO-AIRE® CUTS HOT STRIP MILL LUBRICATION COST 90% ON WORK ROLL BEARINGS!

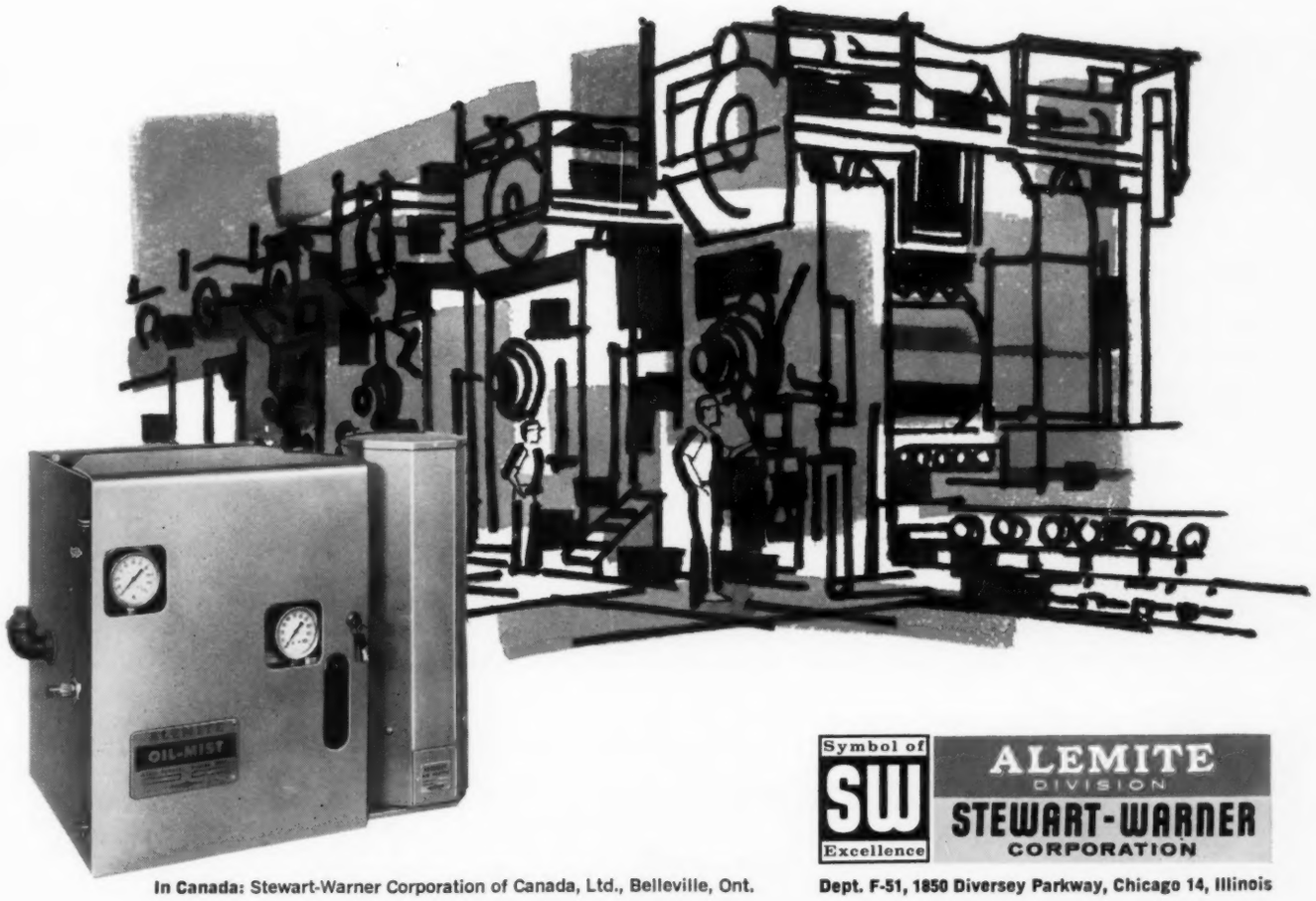
There is no comparison between Alemite Oil-Mist with Thermo-Aire and old-fashioned grease methods!

Take economy. Lubrication savings amount to $32.00 on every turn with Alemite Oil-Mist with Thermo-Aire. Oil-Mist was installed on one stand . . . and is being installed on nine other stands to replace an out-dated system for lubricating 40 roller bearings on an 80-inch hot strip mill. Working 15 turns a week, 52 weeks, these savings will add up to nearly $25,000 a year!

Take efficiency. Alemite Oil-Mist with Thermo-Aire is a fully automatic lubrication system. It applies lubricants constantly, properly, *without losing a minute of valuable production time.* It eliminates expensive packing of bearings with grease and also completely eliminates need to clean bearings of old grease. Its exclusive "Thermo-Aire" feature preheats incoming air—permits atomization of even the heaviest straight mineral oils to supply heavy-duty bearings with the high viscosity lubricants they need for smooth, steady performance.

Alemite Oil-Mist with Thermo-Aire will improve mill operating efficiency. . . lengthen bearing life . . . cut oil consumption and prevent product spoilage.

Write for illustrated brochure form 37-32, or see your Alemite representative for the amazing story of Alemite Oil-Mist with Thermo-Aire and how you can benefit from it!



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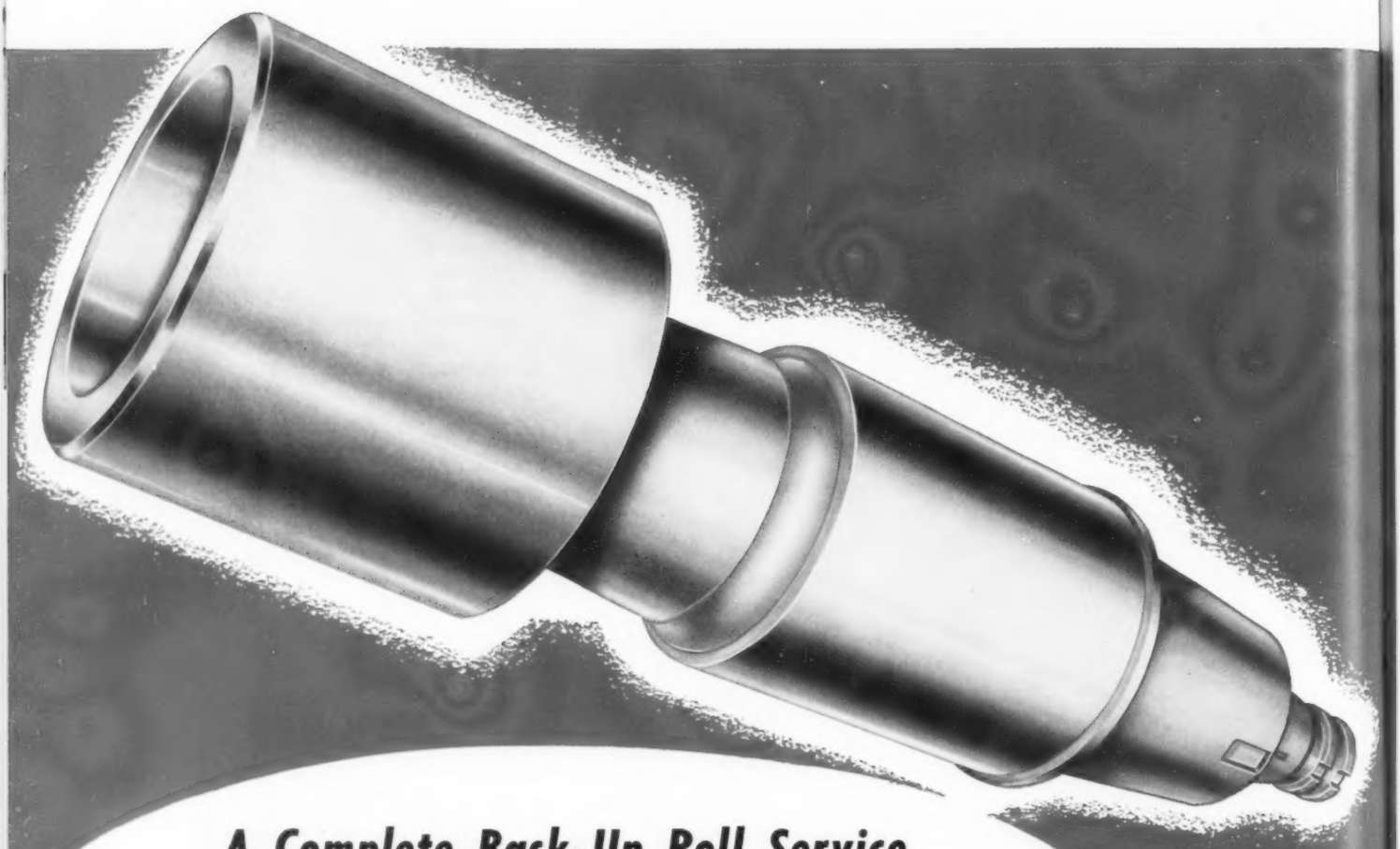

A Complete Back-Up Roll Service

Ohio Steel, manufacturers of all types of iron, steel and forged steel rolls, announces a new complete back-up roll service.
Operations Now Include:

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If you're looking for a complete back-up roll service that'll meet your most exacting specifications, contact your nearest Ohio roll sales engineer.

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Carbon Steel Rolls	Flintuff Rolls	Denso Iron Rolls
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OR-46

Industry News...

BELGIAN PLANT TO ROLL U. S. EXPORTED COILS

△ It is reported that the proposed joint American-Belgian stainless steel company, Allegheny-Longdoz, S.A., will initially roll stainless steel coils supplied by Allegheny Ludlum Steel Corp. starting early in 1963 at their new joint company plant on a 200-acre site at Genk, Limburg, Belgium.

Esperance-Longdoz will also build a new oxygen melting shop at Chertal. It is expected that this will enable Esperance-Longdoz to use their existing steel plant at Seraing for developing production of special steels.

NEW BY-PRODUCT COKE OVEN BATTERY OPERATING

△ The Pittsburgh Works of Jones & Laughlin Steel Corp. has put into operation a new battery of by-product coke ovens.

The new battery, which consists of 59 smokeless ovens, is the second to be put into operation in the past year. Another 59-oven battery went into production in 1960. J&L also has under construction another battery of 118 smokeless coke ovens. It is scheduled for completion later this year.

Completion of the 118-oven battery, together with a six-year-old 79-oven battery, will give the Pittsburgh Works four modern batteries with a total of 315 ovens.

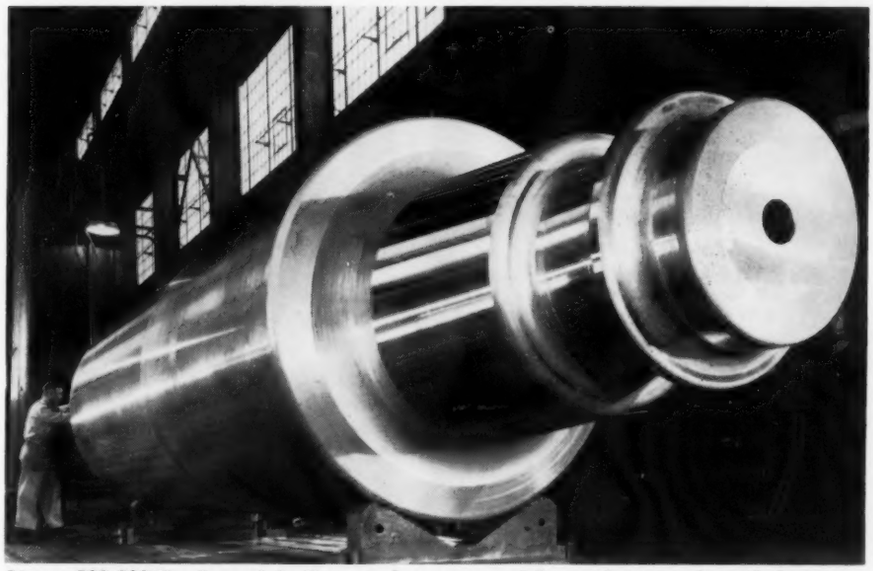
The expanded by-product coke facilities will provide ample coke for the plant's six blast furnaces, and some coke will be shipped to J&L's Cleveland Works, which has no by-product coke plant.

All three new batteries will be similar in that they feature modern, four-divided, low-differential ovens and rotating table charging cars, which permit rapid chargings without smoke emission.

Coal for the ovens will be charged mechanically rather than by gravity for a more uniform distribution in the ovens.

The Wilputte Coke Oven Division of Allied Chemical Corp., which installed the two 59-oven batteries, also is constructing the 118-oven battery.

GIANT BACK-UP ROLL FOR GARY PLATE MILL



About 500,000 lb of special alloy steel was poured from the open hearth furnaces at Mesta Machine Co. to make this huge roll which has a finished diameter of 72 in. and is 29 ft long. It will be used as one of the backing-up rolls in the plate mill which Mesta is building for the Gary Steel Works of United States Steel Corp. This plate mill will be the world's first installation arranged to operate as either a 160 or 210-in. wide mill.

GRANITE CITY BLOWS IN NEW BLAST FURNACE

△ The Granite City Steel Co. has blown in its new blast furnace. It was completed early this year but not blown in at once because the demand for steel was low.

Following a steel industry tradition, the new furnace was christened "Vardi" in honor of the wife of Nicholas P. Veeder, chairman of the board and president of Granite City.

The new furnace is 215½ ft high. It has a 28-ft hearth diam and can produce approximately 2000 tons of pig iron a day. The furnace and its contents will put a load of about 20,000,000 lb on its foundation. The molten iron will be tapped into 200-ton capacity ladle cars and moved along a mile of railroad track to Granite City's open hearth furnaces.

This is only the second blast furnace built in the St. Louis area in the last 35 years. The other, which first went into operation in 1956, stands next to the new furnace. The 1956 furnace and this one replaced two blast furnaces built in the 1920's. The combined annual output of Granite City Steel's blast furnace plant is now rated at about 1,134,000 tons of pig iron.

AWARD CONTRACTS FOR TWO NEW FURNACES

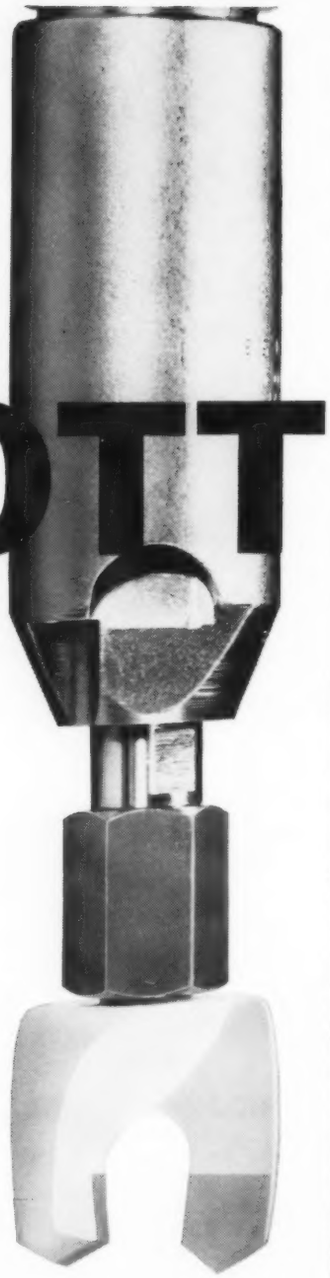
△ Contracts have been signed for the installation of two new slab heating furnaces by Sharon Steel Corp., James A. Roemer, chairman of the board, announced.

In making this announcement, Mr. Roemer said, "This is the third major step we have taken this year to improve the quality of our products and to modernize our facilities.

to clean badly clogged air preheater tubes

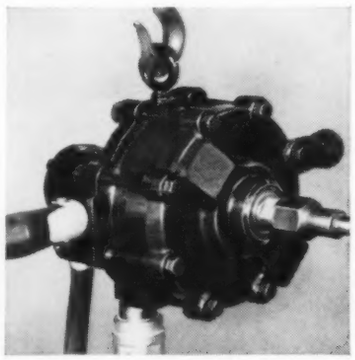
ELLIOTT

heavy duty tube cleaner



Shown above is the powerful Lagonda heavy-duty air motor with carbide-tipped cutter bit. Attached to a flexible air hose, this unit can operate in any position where headroom is limited. The carbide tip will clean even the most badly clogged tubes, quickly and effectively.

Where headroom permits, the heavy-duty suspended-type motor shown at the right can be used to drive a cutting bit attached to a hollow steel shaft, through which flushing and cooling water is fed. This extremely powerful unit can be used either vertically or horizontally.



Full information and prices may be obtained from any Elliott District Sales Office, or by writing Elliott Company, Lagonda Plant, Springfield, Ohio.

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ELLIOTT COMPANY

GENERAL OFFICES: JEANNETTE, PENNSYLVANIA

PLANTS AT: Jeannette and Ridgway, Pa.; Springfield, Ohio

TURBINES • GENERATORS • MOTORS • COMPRESSORS • TURBOCHARGERS
DEAERATING HEATERS • EJECTORS • CONDENSERS • STRAINERS • TUBE CLEANERS

Earlier this year we placed our bright annealing unit in operation. In March we broke ground for a vacuum stream droplet degassing plant to improve the quality of our forging steel. It is scheduled for completion early in the third quarter of this year.

"This latest step, which will involve an extension of our present 24-in. continuous hot strip mill building, has as its sole aim improved temperature control and an increase in the maximum slab thickness used on our 24-in. continuous hot strip mill. The design of the new furnaces is such that it will be possible to simultaneously handle slabs of different physical characteristics so that they can be fed to the rolling mill as required. Provision will be made for observing the operation by closed circuit television."

A new 36-in. diam vertical edger, driven by a 500-hp motor, will break scale and reduce the slab width so that all slabs will be uniform prior to entering the roughing line.

This modernization will also incorporate increased horsepower in the mill drives and relocation of the mill stands for more efficient operation—all of which will be accomplished without interrupting production.

The estimated cost of the improvement is $4,500,000, and completion of the project is scheduled for the spring of 1962.

INLAND TO ADD POWER PLANT AND FOUNDRY

△ Two new major construction projects for Inland Steel Co.'s Indiana Harbor Works have been announced by John F. Smith, Jr., Inland president. They include a foundry for casting ingot molds and a new plant for producing electrical power and steam.

Construction of both projects will begin later this year and will be completed in 1963.

"The ingot mold foundry will enable the company to supply molds for its steelmaking operation at a considerable savings," said Mr. Smith, adding that it would be able to produce 150,000 tons of molds a year, enough to meet the company's needs at capacity levels of operation and would be constructed so that it

SERIES 5000
For intermittent operation . . .
relatively low capacity.

SERIES 6000
For continuous operation . . .
moderate capacity.

759 ways to solve your idler problems

Link-Belt idlers in standard types and sizes to meet every conceivable belt conveyor need

You're sure to find the exact idler to perfectly match your belt conveyor requirements from the complete Link-Belt line of 759 types and sizes.

This broad line enables you to select a size idler that exactly matches your needs, no over- or under-engineering. Power requirements are held to a minimum. In addition, anti-friction bearings, accurate roll alignment and rugged construction provide maximum life for idlers and conveyor belt in light- or heavy-duty service.

Link-Belt idlers are available with end rolls inclined at 20°, 35° and 45° for a broad range of belt widths. Matching lines of troughed belt rubber cushion, troughed belt training, return belt and rubber tread return belt idlers are also available. Call your nearest Link-Belt office or authorized stock-carrying distributor for full details. Look for CONVEYORS in the yellow pages of your phone book. Or write for Book 2716.

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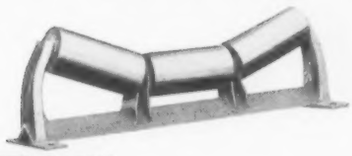

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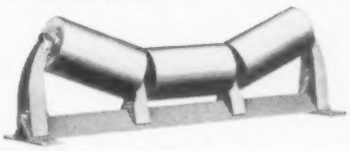
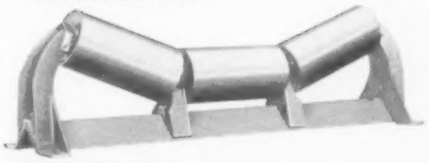
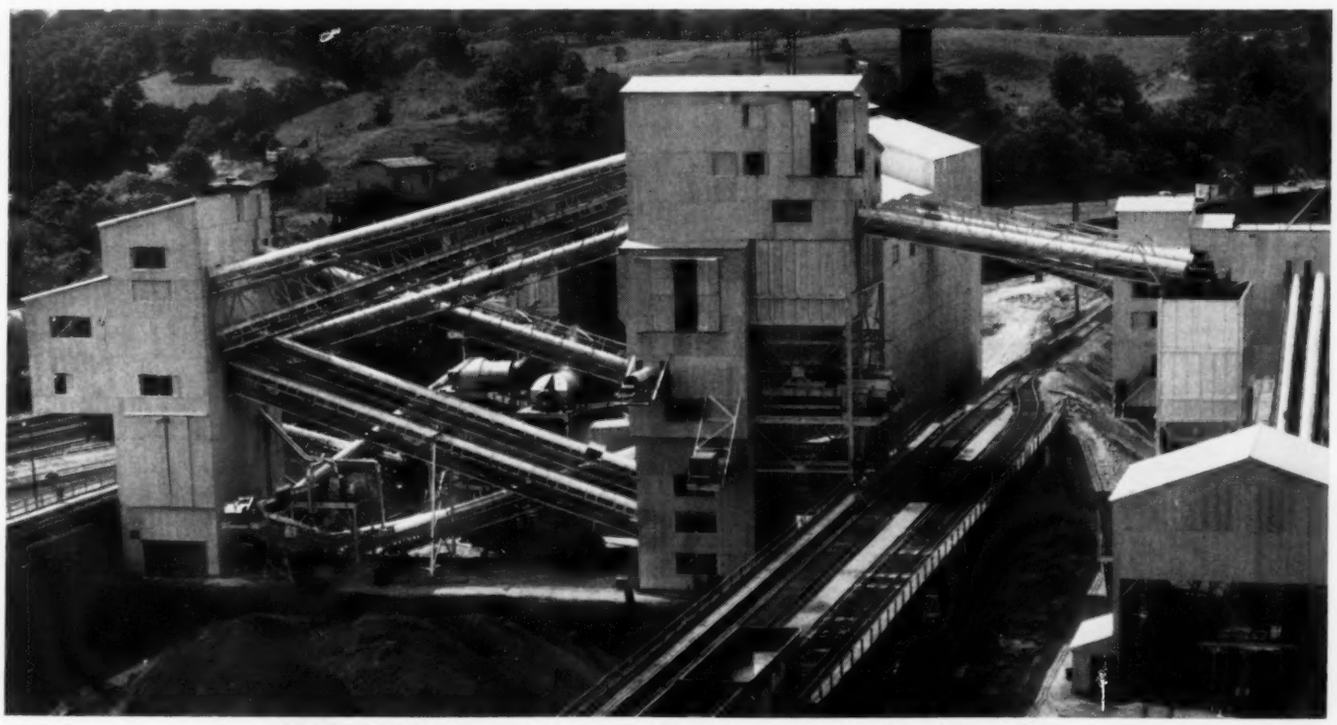
For continuous operation, higher capacities, heavyweight, abrasive materials.



SERIES 8000
For continuous operation, higher capacities, heavier-weight, abrasive materials.



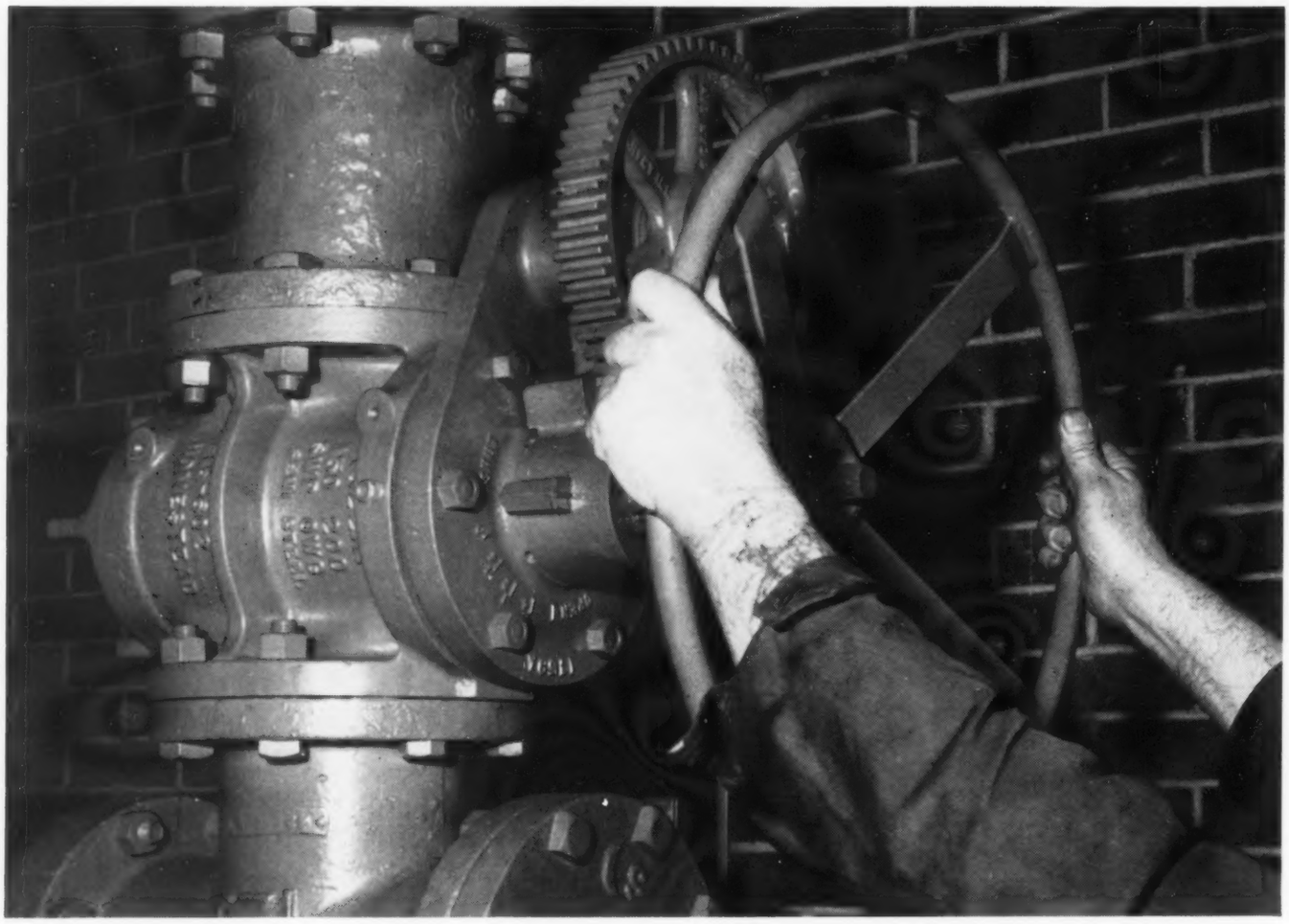
SERIES 9000
For continuous service, highest capacities, heaviest and coarsest materials.



50 BELT CONVEYORS, employing five different sizes of various type idlers, keep raw materials moving steadily through this sintering plant of Armco Steel.

100% FLUID CONTROL AT YOUR FINGERTIPS

with Homestead Lubricated Plug Valves. When open, they provide full pipe-sized passage to fluids. Closed, their controlled high pressure lubricant



system, plus extremely close plug and body tolerance, guarantee a complete chemical seal—positive shut-off without contamination of line fluids. Instant response is sure, too, because piston-like movement of plug during each lubrication prevents sticking. They are low in first cost—low in upkeep. Write for complete details.

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HOMESTEAD VALVE MANUFACTURING COMPANY
P.O. Box 160, Coraopolis, Pennsylvania

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Gentlemen: Please send me Catalog 39-1 and prices on Homestead Lubricated Plug Valves

Name..... Title.....

Company.....

Address.....

City..... Zone..... State.....

could be readily and economically expanded.

The new power and steam producing plant is needed, Mr. Smith said, to supply the plant's increased need for electrical power and steam in its modern new plants completed under the company's recent modernization and expansion programs. "It will not only be able to supply the growing needs of our expanding plant, but will also replace obsolete equipment," he said.

The plant will contain two boilers, a 40,000 kw generator, coal and ash handling systems and other facilities. It will supply about one fourth of the steel plant's power needs. The remainder is furnished by other company power plants and some is purchased.

ARBED OPERATING NEW CONTINUOUS BILLET MILL

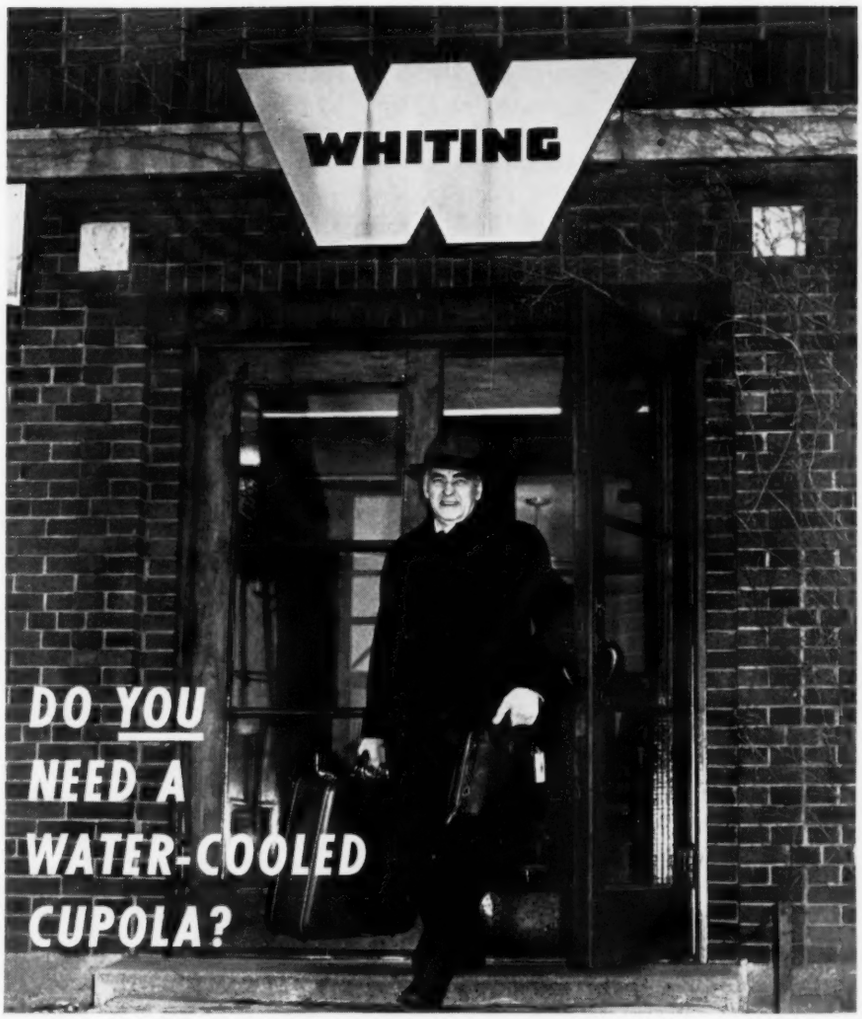
△ A continuous billet mill built by SCHLOEMANN Aktiengesellschaft, Düsseldorf, for the Esch works (Luxembourg) of ARBED has been put into operation. It is designed for the production of 2⅜ in. x 2⅜ in., and 3⅛ in. x 3⅛-in. billets.

As the mill schedule permits the use of uniform roll passes, all the train's eight stands can be powered by a single motor. With the aid of electrical and hydraulic equipment each stand can be shifted to a fixed pass line. All stands are provided with hydraulic roll-changing rigs, so that downtimes are kept to an absolute minimum.

A similar eight-stand continuous billet mill is being built by SCHLOEMANN for the Burbach works (near Saarbrücken) of ARBED. This plant is intended for rolling 2⅞ in. x 2⅞ in., or 3⅛ in. x 3⅛-in. billets respectively. It is scheduled for operation at the end of 1962.

NEW ZEALAND TO STUDY STEELMAKING POTENTIAL

△ The New Zealand government has appointed Battelle Memorial Institute to determine the technical and economic feasibility of establishing an iron and steel industry in that country. According to acting-Prime Minister John Ross Marshall, Battelle will work with the government-owned New Zealand



LET THIS MAN HELP YOU DECIDE!

Walter R. Jaeschke (Jas'ke) is a Whiting consulting metallurgical engineer and an international consultant on foundry cupola problems. His recommendations have slashed melting costs in Europe, South America, South Africa and Japan, as well as for scores of U.S. firms. An authority on water-cooled cupolas, he consulted extensively on the world's largest—built by Whiting for Acme Steel.

If you are seriously debating the merits of liningless, water-cooled cupolas, why not draw on the wealth of this man's experience? He knows intimately the conditions required to make water-cooled cupolas profitable. He also recognizes those circumstances which make them impractical or uneconomical.

Walter Jaeschke is available—without charge or obligation—to survey *your* needs at your convenience. Whatever his recommendations, they will be based on the dollars-and-cents requirements of your particular operation.

FREE: Bulletin FY-176, *Water-Cooled Cupolas.* Write Whiting Corporation, 15655 Lathrop Avenue, Harvey, Illinois. In Canada: Whiting Corporation (Canada) Ltd., 350 Alexander Street, Welland, Ontario, Canada.

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FOUNDRY EQUIPMENT

Steel Investigating Co. on all phases of its iron and steel investigation.

H. W. Lownie, Jr., chief of process metallurgy research at Battelle, said that the Columbus, Ohio, research center's primary task is to determine which steelmaking process is best suited to New Zealand's raw materials—especially the country's iron-containing beach sands. The project is expected to be completed in six months.

Battelle process metallurgy experts will obtain the necessary technical and economic information, conduct on-the-spot surveys of the situation, and meet with the industry and government officials connected with the venture. After their return to Columbus, they will join other Battelle technical and economic specialists in analyzing the information and preparing recommendations.

Battelle has conducted similar studies in a number of other countries. Among recent major projects were a study on methods of utilizing Spain's iron and coal resources and a study of ore-reduction problems at Venezuela's new national steel plant.

PREVIOUS AGREEMENT EXTENDED BY FIRMS

△ The previous agreement between the Siemag-Group (Siemag Maschinenbau und Stahlbau Netphen GMBH) and Morgan Engineering Co., Alliance, Ohio, to permit Siemag Netphen to furnish soaking pit and stripper cranes, has been extended to cover charging equipment.

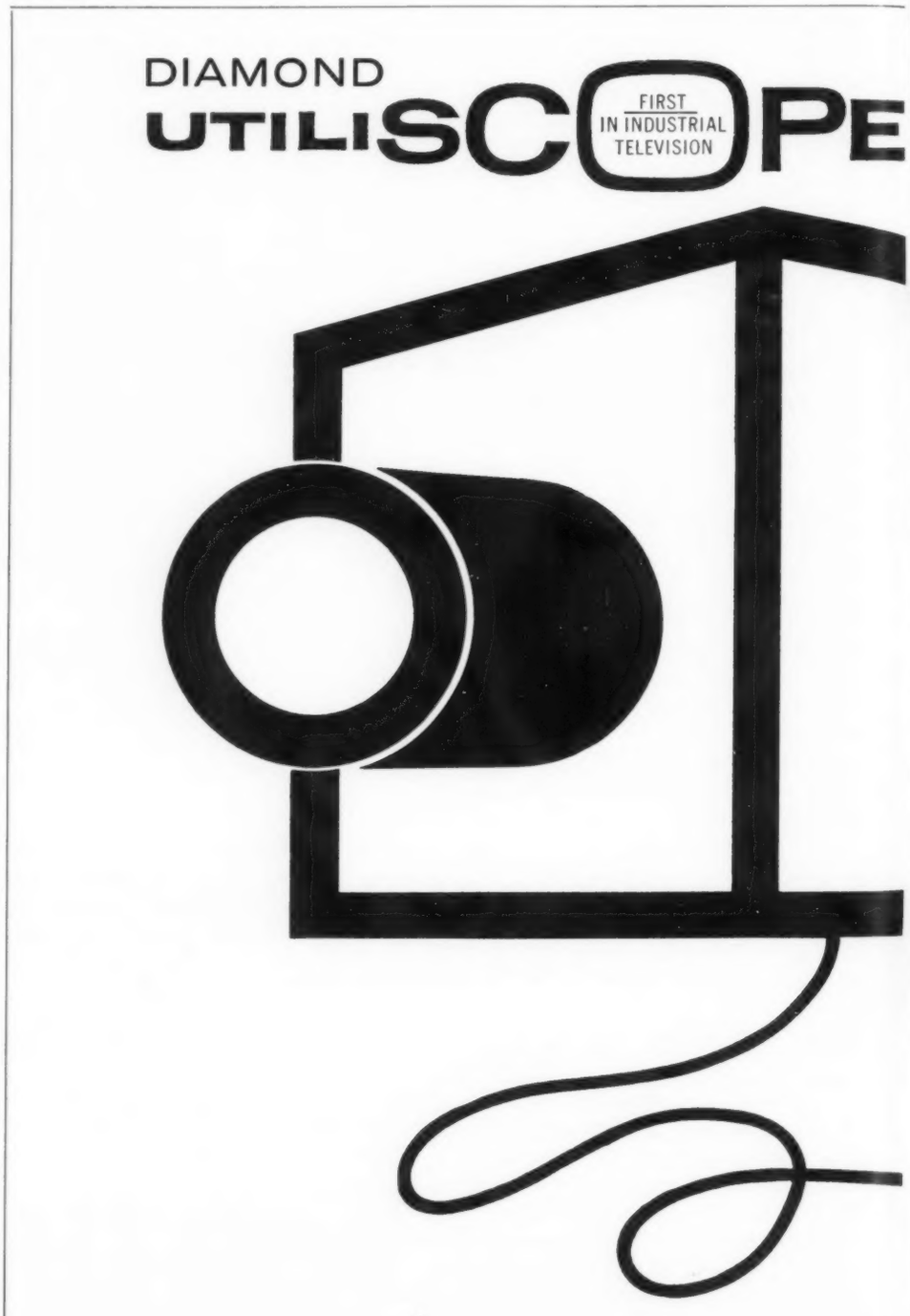
As a result of the previous agreement, an order has been received from a Swedish steel company for a 385-ton stripper crane. Tong stroke speed will be 52.5 fpm, and the stripper speed will be 13.1 fpm. The tongs will be able to revolve at four rpm. Bridge travel speed is 328 fpm and trolley travel speed is to be 164 fpm. Opening and closing of the stripper tongs takes place by electrohydraulic means. Power to unit is furnished by flexible rubber covered cables.

WESTINGHOUSE EQUIPS ACME ROUGHING MILL

△ The Westinghouse Electric Corp. supplied the electrical drive and "Prodac" control apparatus for the Acme Steel Co.'s new reversing roughing mill at Riverdale, Ill.

The roughing mill reduces 4½-in.-thick by 30¾-ft-long slabs to ⅝-in.-thick steel plates for further rolling in the hot-strip finishing mill. Slabs from 10¾ to 31 in. wide can be handled through this equipment in five passes. Before entering the rougher the slabs receive about five per cent thickness reduction in a horizontal scale breaker. The entire reversing roughing mill cycle requires approximately 65 sec.

The control system automates the mill operation from a schedule recorded on a punched card. The control automatically directs the horizontal roll opening, entry and delivery edger roll openings, mill and table speeds, cycle operation, draft compensation and descaling operation. The operator may intervene and work the mill with manual controls at any point in the rolling cycle and return to automatic operation to complete the cycle. In addition, the control makes it possible to use the full mill capacity on a continuous basis. The gage and width



accuracy of the delivered plate is better than normally possible with a conventional manually controlled mill.

The main horizontal stand is powered by a 4500-hp, 60/150-rpm d-c motor drive. Vertical edging mills are located on both the entry and delivery sides of the horizontal work rolls and edge reductions are taken ahead of each flat pass. Each edging mill is powered by a 500-hp, 340-rpm d-c motor. The total power for the main and auxiliary drives is about 900 hp.

GARY MILL CONTRACT AWARDED TO MESTA

△ Mesta Machine Co. has been awarded a contract to cover the design and manufacture of a 60-in. continuous galvanizing and aluminum coating line for steel strip to be installed at the Gary Sheet & Tin Mill of U. S. Steel Corp.

It will be an all-purpose line capable of producing galvanized and aluminum-coated steels in widths up to 60 in. and in thicknesses ranging from 14 through 28 gage, in coils and cut lengths. In addition to uniform application of zinc or aluminum coating, this line will also apply a differential coating to the steel strip. In the differential process, a heavy coating is applied to one side of the strip while a lighter coating is applied to the other side. A Bonderizing unit will also be incorporated in this processing line to provide paint-adherent properties on the zinc coated strip.

The coil entry equipment will be designed to handle coils up to 72 in. in diam, with a maximum weight of 60,000 lb and will include two payoff reels, double cut shear and an automatic mash welder to join the coils for continuous operation. The delivery equipment will be designed to handle galvanized or aluminum coated coils weighing up to 30,000 lb or sheets in lengths from 3 to 16 ft.

This new continuous galvanizing and aluminum coating line will provide Gary Sheet & Tin with facilities for the production of steel strip for corrosive and heat resistant applications, among which will be aluminum coated steel strip.

JAPANESE FIRM LICENSED TO BUILD GAS TURBINES

△ Mitsubishi Heavy Industries, Reorganized, Limited, of Kobe, Japan, will begin manufacturing gas turbines this year under a license and technical assistance agreement announced by the Westinghouse Electric International Co.

Under the agreement, Westinghouse will provide Mitsubishi with designs and engineering information and with material and process specifications for the manufacture of nonaviation open-cycle gas turbines, according to D. E. Akins, vice president of Westinghouse International.

Mr. Akins said this agreement is the second which Westinghouse International has signed with this Japanese concern. The first, signed in 1952, covers steam turbines for industrial and marine applications, heat exchangers and reduction gears.

Mitsubishi Heavy Industries, Reorganized, operates in seven principal fields: shipbuilding, railway rolling stock, motor vehicles, aircraft, prime movers, industrial machinery and agricultural machinery.

"TAILORED" FOR THE TOUGH TESTS OF IRON AND STEEL

Closed-circuit television for iron and steel mill applications takes a "toughness" you'll find only in Diamond Utiliscope. Despite extreme heat, magnetic dust, vibrations or shock, Utiliscope provides reliable and accurate viewing of blast furnace and coke oven interiors plus a whole range of rolling and finishing operations . . . all from one safe, central control point. Regardless of *your* application, there's a Diamond Utiliscope System to help you save money by improving operations. The coupon below will bring complete information.

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Please send complete information on how Diamond Utiliscope can help reduce operating costs and improve operations.

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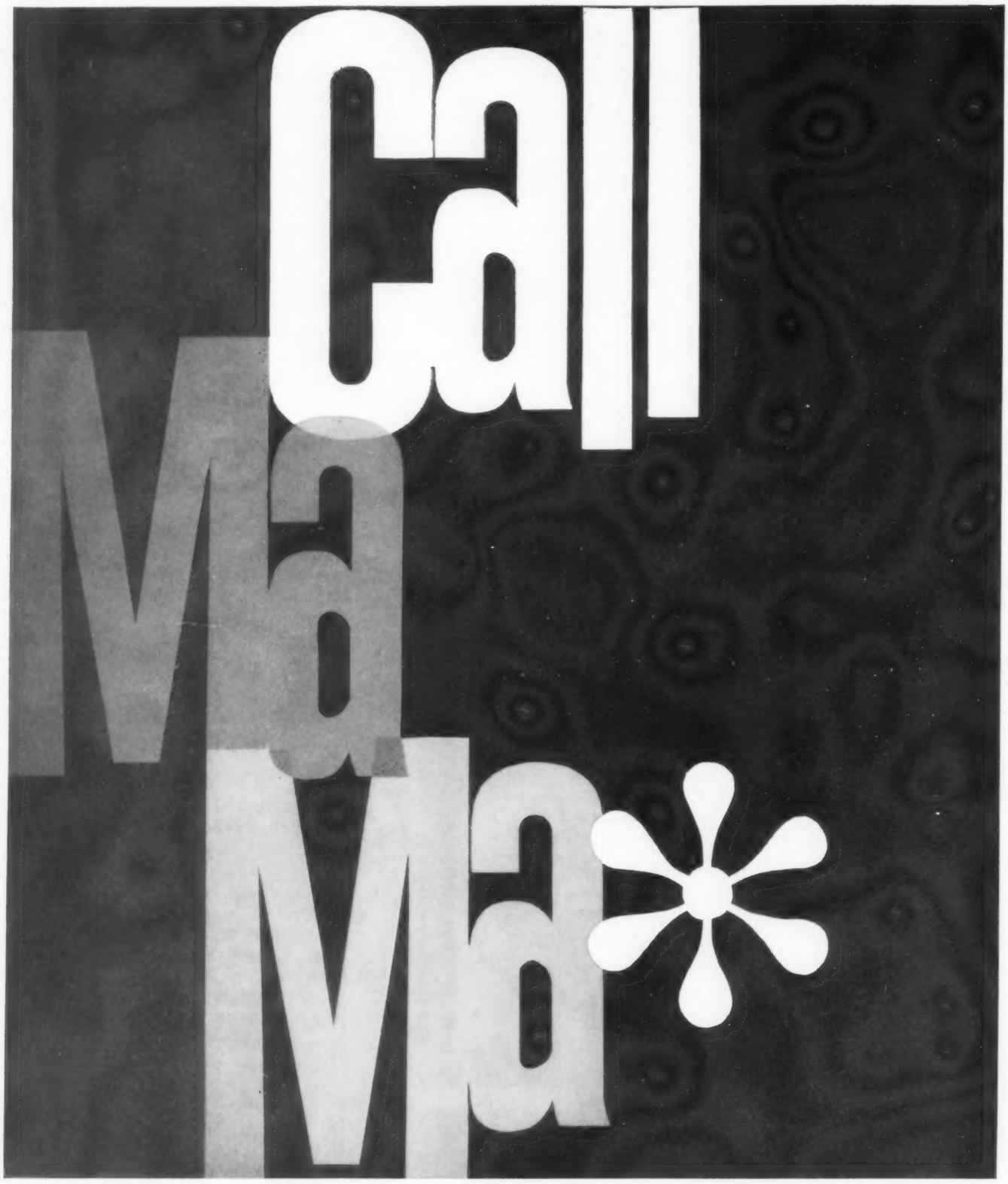

*MAchinery-MAintenance Division of CORONADO STEEL COMPANY builds original, replacement and spare parts for Mill-Type equipment. MA MA is ready to help you on any parts problem. MA MA reliability and know-how saves you money and insures fast delivery. We ask only for the opportunity to bid . . . from your blueprints . . . on your next parts problem. Call MA MA . . . next time!

CORONADO STEEL COMPANY MACHINERY-MAINTENANCE DIVISION
WEST COMMERCE AND NORTH AVENUE • AREA CODE 216 • RIVERSIDE 7-4436 • YOUNGSTOWN 3, OHIO

MORE THAN 100 P-A VENTURI GAS WASHERS NOW OPERATING IN THE STEEL INDUSTRY

Efficiency and economy proven for blast furnaces, open hearth furnaces, oxygen steel converters, electric furnaces and sintering plants.

Chemico venturi washers offer the following major advantages: low initial cost; virtually no maintenance; minimum space required; cleaning efficiencies approaching 100% can be obtained; adjustable controls maintain maximum efficiency at all rates of flow; recirculation minimizes water consumption; solids can be recovered in dry condition; and, power requirements on venturi washers are as low or lower than precipitators for open hearth furnaces and oxygen steel converters.
If you are considering the purchase of gas cleaning equipment, let Chemico show you how venturi washers are performing at steel plants from coast to coast.

CHEMICO

Chemical Construction Corporation, Gas Scrubber Division
320 Park Ave., New York 22, New York
Ferndale, Mich.
Chicago, Ill.
Los Angeles, Calif.
Houston, Tex.
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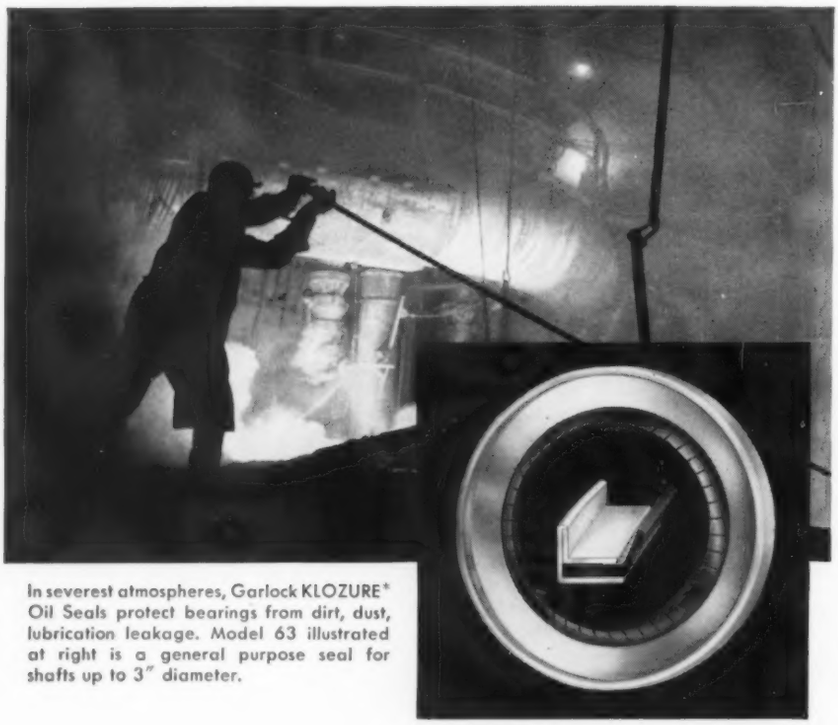
Pittsburgh, Pa.

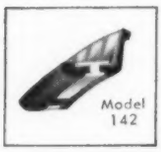
ENGINEERED OIL SEALS
for Steel Mills



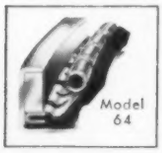
In severest atmospheres, Garlock KLOZURE* Oil Seals protect bearings from dirt, dust, lubrication leakage. Model 63 illustrated at right is a general purpose seal for shafts up to 3″ diameter.

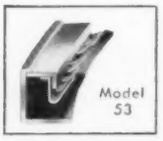
Where there is the slightest possibility of bearing damage due to oil leakage, apply Garlock KLOZURE Oil Seals.

Everywhere in steel—on hot and cold strip mills, blooming and structural mills—Garlock KLOZURE Oil Seals prevent leakage of vital bearing lubrication. And they further prevent damage to the bearings by sealing out scale, spray, dirt, and other foreign matter.

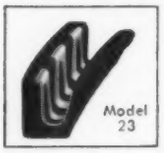


For example, Model 142, a face-type oil seal, is designed to seal surfaces perpendicular to shaft . . . keeps water splash and scale out of bearings at the shoulder of mill rolls. Models 64 and 82 are applied to large shafts at normal or high speeds . . . ideal for protecting bearings on back-up and work rolls. Model 53 withstands temperatures up to 250°F at normal or high speeds . . . recommended for table rolls. Where equipment can't be dismantled easily, Model 23 Split-KLOZURES are the choice.





All KLOZURE Oil Seals are oil and grease resistant . . . impervious to water, mild acids, alkalies . . . non-abrasive . . . withstand temperatures from −40°F to +250°F. For extreme conditions, Garlock furnishes sealing elements resistant to practically any fluid, and serviceable as high as +500°F.



Enjoy prompt "off-the-shelf" delivery. A new, nationwide stocking program places over 1800 standard stock items of Garlock KLOZURE Oil Seals near you. All you need is a telephone for quick service on a badly-needed replacement oil seal, or to replenish your current stock of seals. For the name and address of the authorized Garlock KLOZURE Oil Seal distributor in your area, call the closest of the 26 Garlock sales offices and warehouses

GARLOCK

throughout the U.S. and Canada. Or, for further oil seal data, write for Catalog AD-181, Garlock Inc., Palmyra, N.Y.

Canadian Div.: Garlock of Canada Ltd.

Plastics Div.: United States Gasket Company

Order from the Garlock 2,000 . . . two thousand different styles of Packings, Gaskets, Seals, Molded and Extruded Rubber, Plastic Products.

*Registered Trademark

B-L-H Loewy expanding and pipe testing equipment . . . high production, fully automatic, flexible

Combining two separate operations—full length expanding and hydrostatic testing—in one unit, B-L-H Loewy equipment assures pipe that is free of welding defects, true to dimensions, and of expanded physical properties.

Fully automatic, B-L-H machinery maintains high production rates. Large filling valves and specially designed purge valves assure rapid and trouble-free operation. Flexibility is another important feature. Special design permits quick change of the expander from one pipe diameter to another. And pipes varying in length from 15 to 55 ft. can be processed within the same production run.

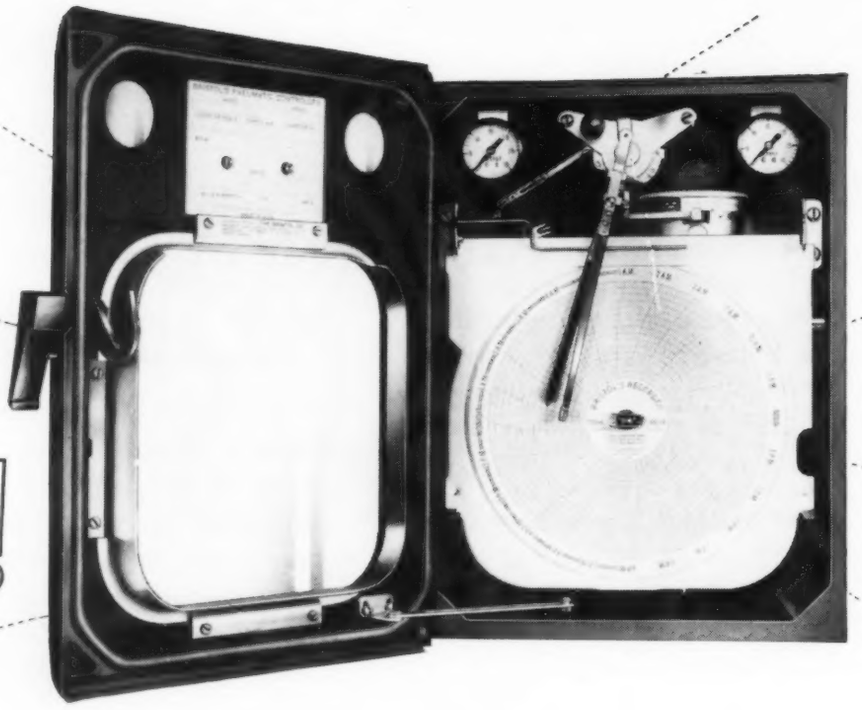
The B-L-H line of testers is specifically designed to meet the maximum pressures of the API standards. Testers for extreme pressures are completely enclosed in a heavy safety shroud with automatically operated doors to protect the operator and other personnel. For further details about our expanders and pipe testers or for information about our automatic pipe inspection and data processing equipment, write us at Dept. C-5.

Artist's rendering of typical B-L-H Loewy pipe mill

BALDWIN · LIMA · HAMILTON

Industrial Equipment Division · Philadelphia 42, Pa.

NEW!



Bristol Series 532 A/D* pneumatic recording controller is outstandingly SIMPLE, RELIABLE, and STABLE

- **Simple modular design for ease of servicing**
- **High control stability for closer process control**
- **Designed for batch-type and continuous processes**
- **Proportional, proportional-plus-reset, and proportional-plus-derivative control models available**

Top control performance with maximum simplicity plus standard Bristol precision measuring elements—those are the key features of the Bristol Series 532 Recording Controller. The 532 uses the same renowned elements that have earned such a reputation for accuracy and dependability on other Bristol automatic controlling and recording instruments—perfected through wide experience and many years of development.

Self-contained modular design of the control unit speeds servicing. The whole modular unit, consisting of an aluminum casting with working parts made of stainless steel, Ni-Span C, and Neoprene diaphragms, can be removed by taking out only two screws and a link.

The die-cast aluminum instrument case (15¾ x 10¾ x 5¾ overall) presents a streamlined appearance and is completely dustproof and weatherproof.

Write for complete data on the new, versatile, economical 532 A/D. The Bristol Company, 123 Bristol Road, Waterbury 20, Conn., a Subsidiary of American Chain & Cable Company, Inc. 0.46

ACCO

CONTROL UNIT CHARACTERISTICS:

PROPORTIONAL BAND: 0-400% continuously adjustable, direct- or reverse-acting.

RESET: 0.1 to 100 repeats per minute.

DERIVATIVE: 0 to 10 minutes derivative time.

AIR PILOT: Non-bleed type.

PILOT CAPACITY: Over 3.0 scfm.

FREQUENCY RESPONSE: Essentially flat to 300 cycles per minute.

TEMPERATURE STABILITY: Less than 0.1% change in the output pressure for 90°F temperature change.

CHART: 8″ diameter; wide variety available.

MATERIAL: Aluminum housing; 316 stainless steel internal parts; Ni-Span C feedback element.

RECORDING CONTROLLERS OFFERED FOR:

PRESSURE AND VACUUM: Ranges from full vacuum to 15,000 psi.

TEMPERATURE: Ranges from −100°F to +1000°F.

FLOW AND DIFFERENTIAL PRESSURE: With mercury-type manometer and dry-type differential unit.

LIQUID LEVEL: With bulb unit and mercury manometer and dry-type differential unit.

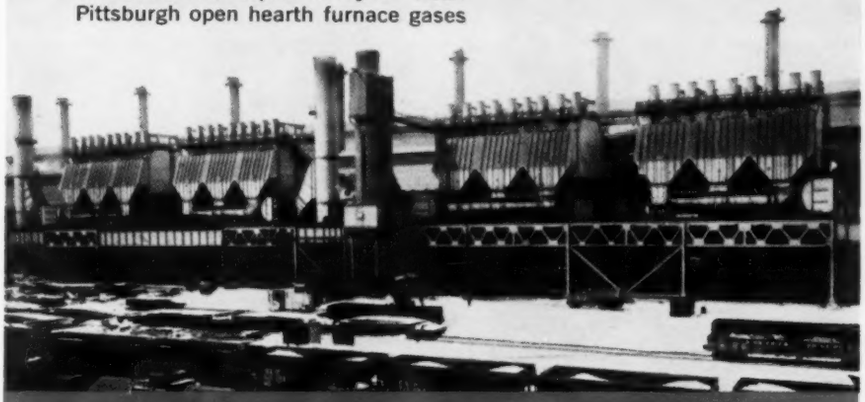
HUMIDITY: Zero to 100% relative humidity.

**Advanced Design*

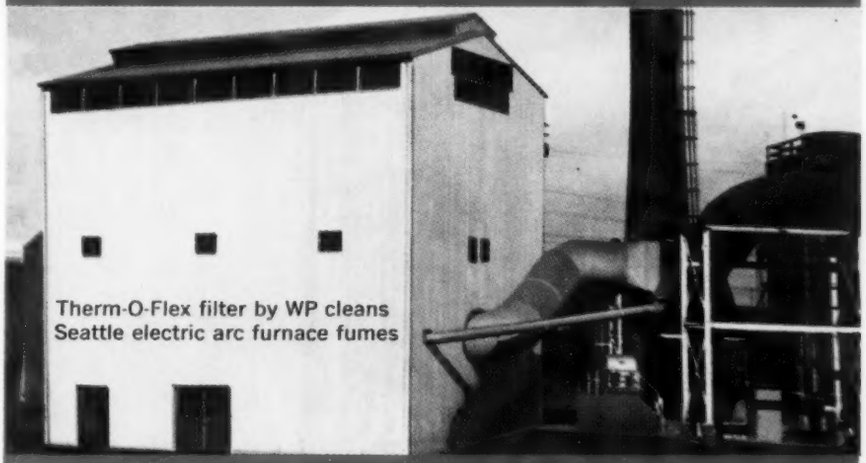
BRISTOL ... for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

Electrostatic Precipitators by WP clean
Pittsburgh open hearth furnace gases



**Open hearth steel in Pennsylvania...
and electric arc in Washington...agree:**



Therm-O-Flex filter by WP cleans
Seattle electric arc furnace fumes

When DUST is your problem— CLEAR IT WITH WP*

For an efficient, economical solution to any dust control problem—look to Western Precipitation. WP is uniquely fitted to handle your unique problem—being the one organization that custom designs, engineers and installs ALL types of dust and fume control equipment: Precipitator, Mechanical, Jet-Cleaned Filter, Hi-Temp Filter, scrubbers and engineered combinations.

With no axes to grind for any one system, WP engineers will give your job a completely unbiased recommendation—whether it's a quote on your specifications, a single component, or a completely engineered installation . . . small, major, simple, or complex.

An inquiry—on your business letterhead—will bring you literature promptly. Just write Western Precipitation, 1000 W. 9th St., Los Angeles 54, Calif. (In Canada, write 8285 Mountain Sights Ave., Montreal, P.Q.)

Dust and fume control since 1907

*WESTERN PRECIPITATION

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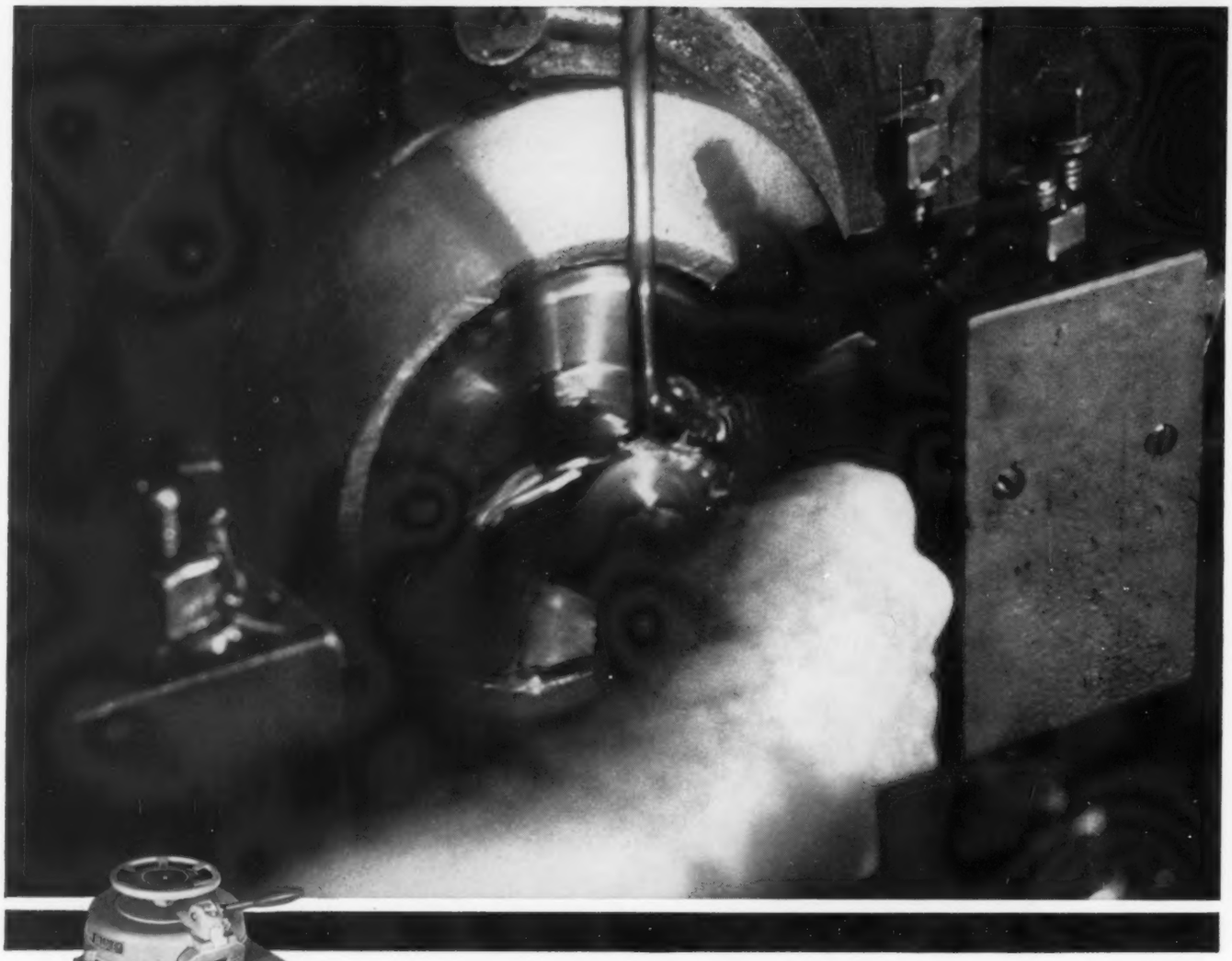
Division of Joy Manufacturing Company

ELECTROSTATIC Precipitators
MULTICLONE Collectors
CMP Combination Units
DUALAIRE Jet-Cleaned Filters
THERM-O-FLEX Hi Temp Filters
TURBULAIRE Scrubbers
JOY-MICRODYNE Scrubbers
also: **HOLO-FLITE** Processors
HI-TURBIANT Heaters
TURBULEX Calciners



COOL CUTS

Keeping close tolerances is of prime importance at Diagraph-Bradley Industries, Inc., of Herrin, Illinois, leading manufacturer of stencil machines and accessories. One of the ways this is accomplished is by keeping cutting edges cool.

At Diagraph-Bradley stencil punches must be cut and held within .0005 of an inch—a fine point of precision Diagraph-Bradley attributes to the cooling and lubricating effect of Cities Service Chillo 10 cutting oil.

"You have only to take a Diagraph-Bradley machine," says one of the company officials, "cut a stencil with it and look at the resulting letter to realize how important the right cutting oil is to our production."

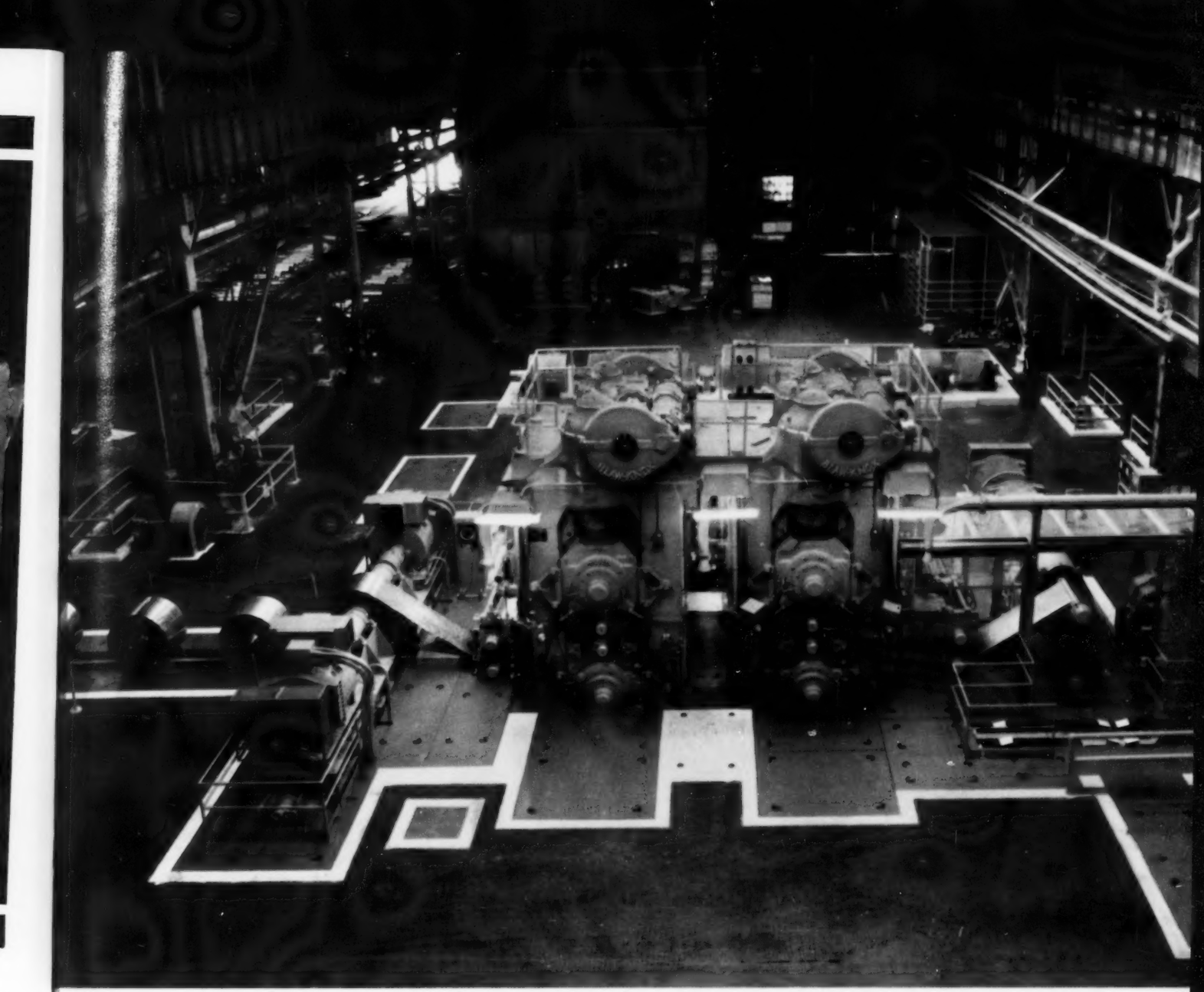
Cities Service Chillo 10 oil is a sulphochlorinated oil. The concentrations of sulphur and chlorine are stabilized by a special process, assuring uniformity of action through the entire cutting operation.

That's why, with Cities Service Chillo 10 cutting oil, work is always more accurate, clean and cool!

For full information call your nearest Cities Service office or write Cities Service Oil Company, Sixty Wall Tower, N.Y. 5, N.Y.

CITIES SERVICE

QUALITY PETROLEUM PRODUCTS



19- and 53-inch x 48-inch high speed 2-stand Temper Mill.

BLAW-KNOX TEMPER MILLS

Blaw-Knox designs and builds a full range of two high and four high Temper Mills for integration into sheet, strip, and tin plate processing operations. Other Blaw-Knox equipment for the metals industry includes complete rolling mill installations and auxiliary equipment for ferrous and non-ferrous metals, sheet and strip processing equipment, electrolytic tinning, annealing, and galvanizing lines, seamless pipe and tube mills, draw benches, and cold draw equipment, Blaw-Knox Medart cold finishing equipment, iron, alloy iron and steel rolls, carbon and alloy steel castings, fabricated steel plate or cast-weld design weldments, steel plant equipment, and heat and corrosion resisting alloy castings. Blaw-Knox Company, Foundry and Mill Machinery Division, Blaw-Knox Building, 300 Sixth Avenue, Pittsburgh 22, Pa.

BLAW-KNOX

Blaw-Knox designs and manufactures for America's growth industries: METALS: Rolling Mills • Steel Processing Lines • Rolls • Castings • Open Hearth Specialties • PROCESSING: Process Design, Engineering and Plant Construction Services • Process Equipment and Pressure Piping • CONSTRUCTION: Concrete and Bituminous Paving Machines • Concrete Batching Plants and Forms • Gratings • AEROSPACE: Fixed and Steerable Antennas • Radio Telescopes • Towers and Special Structures • POWER: Power Plant Specialties and Valves

Morgan Crane selected for wide mill expansion program

This Morgan stripping crane was recently installed at Alan Wood Steel Co. in Conshohocken, Pennsylvania, in connection with their wide mill expansion program. Advanced features such as auxiliary hoist, stool breaker, 400-ton stripping capacity and traditional Morgan efficiency have been included in this universal type ingot stripping crane.

For large tough jobs where efficiency and dependability are a *must*, Morgan cranes pay off time after time. This is one of the reasons Morgan Engineering gets so many repeat orders from its customers.

If cranes are included in your expansion or modernization plans, be sure to get in touch with the Morgan people.

THE MORGAN ENGINEERING CO. *Alliance, Ohio*

Overhead electric traveling cranes, gantry cranes, open hearth special cranes, blooming mills, structural mills, shears, saws, auxiliary equipment and welded fabrications.

Publication Service...

MAY, 1961

You Can Obtain . . .

. . . any of the bulletins reviewed in the Publication Service of the IRON AND STEEL ENGINEER without obligation or cost. Simply circle the desired item numbers on one of the prepaid postal cards and mail. The requests will be forwarded to the manufacturers involved who will send the bulletins to you.

Note: Post cards expire three months after publication date.

(1) Industrial Trucks

An engineering case book discussing the role of "special" electric industrial trucks in diverse operations has been published by The Elwell-Parker Electric Co. Appearing as an edition of the company's periodic material-handling magazine, the literature defines a "special" truck as one which has undergone a basic modification other than use of a simple attachment. This case book explains the place of the "special" in today's material handling operations, describes jobs best suited to special models, analyzes the economics of the units, and includes a check list to aid the potential user in considering specials as the solution to his problem applications.

(2) Insulated Cables

Latest information on cables insulated with OKONEX butyl-base high voltage insulation is available in a 48-page manual issued by The Okonite Co., Div. of Kennecott Copper Corp. This service-proved butyl-base rubber insulation for multi-purpose service up to 90 C, is extremely resistant to ozone, heat and moisture. Engineers will find the data on current carrying capacities, dimensions and the various designs available helpful in designing and specifying efficient electrical systems. (Bulletin 1131)

(3) Combustion Controllers

Combustion controls for furnaces, ovens and boilers are described in an 8-page bulletin released by The North American Mfg. Co. Gas pressure and furnace pressure control, ratio control and flow control are discussed. Furnace pressure controls continuously detect and automatically correct changes in furnace pressure by adjusting dampers. Pressures usually can be held to within plus or minus 0.005 in. wc of the set point. Large 16-in. diaphrams allow maximum sensitivity, and hydraulic pressures adequately operate the heaviest dampers. Standard control range is minus 0.05 in. wc to plus 0.15 in. wc, but other ranges are available for specific applications. Four other signal systems are offered for controlling line pressures from minus 1 in. wc to 1000 psi. For proper fuel/air proportioning, a double diaphram system connected to prestaps at metering orifices is used. As a temperature controller varies the amount of fuel required, the ratio controller provides the correct amount of air, automatically holding the same fuel/air ratio at all firing rates. Flow controls are designed so that a hydraulic relay is actuated by a flexible diaphram, across which has been connected the differential pressure created by an orifice plate. Required flow can be set by adjusting a calibrated spring (Bulletin 3-001)

(4) Tractors

The Eimco Corp. announced the publication of a twelve-page booklet. Included are some direct comparisons between the company's line of diesel powered crawler-tractors and loaders and competitive equipment. Highlighted are power-team, unique operator positioning, track oscillation with all attachments, use of alloy and other steels and full one year warranty. (Bulletin L-1126)

(5) Heat-Treat Bulletin

A new six-page bulletin, published by Surface Combustion Div. of Midland-Ross Corp., is fully illustrated and covers the application of vertical and horizontal equipment for processing continuous strip. Heat treatments discussed are for ferrous and also nonferrous strip metals, and involve annealing, normalizing and galvanizing processes. The many facets of processing strip metal are illustrated which include mechanical handling and feeding equipment; line drive machinery; electric line drives; tension control; roll design; strip tracking, surface protection, splicing, cleaning, drying, heating and cooling. The bulletin also covers the latest generator equipment for prepared atmospheres used in the continuous processing of coiled metal. (Bulletin SC-183)

(6) Graphites

Speer Carbon Co. has announced the availability of a technical bulletin that discusses the company's line of ultra-pure graphites. Total impurity content of these graphites is measured in parts per million rather than on a percentage basis. The bulletin reviews applications, purity limits, available sizes and physical properties. A graph shows variation of gas content for typical grades. Data on the physical properties of various forms of pure graphite, both molded and extruded, are presented in tabular form.

(7) Arc Welding

Information concerning their full line of arc welding products is contained in The Lincoln Electric Co.'s bulletin on arc welding electrodes, equipment and supplies. This bulletin presents information on AWS electrode classification and discusses correct electrode selection for every type of welding applica-

tion. Arc characteristics, welding procedures and physical properties are listed for each electrode including stainless steel, cast iron, and hardsurfacing types, as well as those designed for mild and low alloy, high tensile steel welding. In addition, the bulletin supplies descriptive information on the performance and construction features of a full line of arc welders; including electric and gas engine driven generators, transformer and transformer rectifier designs, as well as their welding supplies. (Bulletin 7000.7)

(8) Refractories

A new folder describing the use of their products in open hearth furnaces has been produced by The Ramtite Co. It explains the features of the plastic products and their use in checker chambers and fan tails, uptakes, spouts and runners, slag run-off spots, hot metal mixers, torpedo and blast furnace ladles. It also shows the open hearth applications of the Ramtite family of refractories for initial installations and gunned resurfacing. As disclosed by a chart, the gunning of torpedo or blast furnace ladles saved seven days of outage time.

(9) Motor Insulation

The Louis Allis Co. recently announced the addition of "Capsulex" insulation system, that has been especially developed for encapsulated formed coils used in large a-c motors ranging in sizes from 200 to 2000 hp. The new insulation system provides added protection to windings against moisture, chemicals, oils and abrasive contaminants, allowing increased life for open motors used in unfavorable environmental conditions. The system features rectangular copper conductors covered with a basic insulation of fused dacron and fibers, which are formed and impregnated with a high-dielectric, insulating varnish that penetrates the spaces between the conductors and augments the basic insulation on the copper. The formed coils are encapsulated with silicone elastomer and armoured with a polyester web tape which is silicone impregnated. The coils are then vulcanized, providing a completely sealed protective sheath. The system is available in open, drip-proof, splash-proof and weather protected motors built in frame sizes larger than 445U for operating voltages of 208 to 5000 volts. (Bulletin 3700)

(10) Electric Manual-Automatic Control Station

A publication describing an electric manual-automatic control station is available from Republic Flow Meters Co., subsidiary of Rockwell Manufacturing Co. The type AMA control station is designed for use in electronic systems to provide a visual check on system response and to select either the manual or automatic control function. This publication provides information on the features, function, available accessories and technical specifications of the unit. It also gives a technical description of the control station. (Publication SRM 463.21)

(11) Limit Switches

A two-page bulletin describes General Electric Co.'s. CR115 B precision snap-action limit switches for highly-repetitive operation in limited-space industrial applications. Photos show the three available forms—button operated, plunger operated and roller-lever operated forms. Typical application is also pictured and dimensions, ratings and pricing information are included. (Bulletin GEA-7319)

(12) Kiln Scanning Pyrometer

The Leeds & Northrup Co. Rayoscan detector, a pivoting pyrometer system that detects impending hot spots on the shell of a rotary kiln or other high temperature vessel, is the subject of a 4-page data sheet available from the company. The publication describes the advantages of automatic hot-spot detection, and explains how the Rayoscan system is applied for continuous and reliable monitoring of kiln-shell temperatures. Featured is a complete description of the unique pivoting-detector unit which can be mounted with only two bolts to any nearby surface, beneath, beside or above the kiln, and which does not require specially built traversing mechanism or structural support. The sheet includes photographs and diagrams illustrating all details of the equipment and its installation. A listing of specifications and ordering instructions completes the data. (Process Data Sheet 705(3))

(13) Motor Controls

A line of motor controls suitable for full voltage operation of synchronous motors is described in a bulletin published by Electric Machinery Mfg. Co. The units are for motors rated 600 volts and below. They feature front accessibility, 10-gage steel enclosures, polarized field frequency control, a heavy duty air break contactor and are built to NEMA, Class A, Type I specifications. Optional control equipment includes weather-proof construction, custom relaying, 110-volt control circuits, disconnect means and special unloader interlocking. (Publication 3100-PRD-269)

(14) Duty Master Motors

A Reliance Electric & Engineering Co. bulletin illustrates and describes the complete line of duty master a-c motors from 1 to 2000 hp. Product features of each motor are clearly outlined and explained for easy selection of the right motor for every application. Accompanying the photos and description of the motors is a detailed description of the production facilities and procedures which are used to manufacture duty master motors. (Bulletin B-2515)

(15) Furnace and Oven Controls

Minneapolis - Honeywell Regulator Co. has published a revised furnace and oven controls bulletin containing 40 pages of information and prices on "ElectroniK 15" potentiometers, millvoltimeters, thermocouples, radiamatic detector, thermometers, flame safeguard systems, industrial controls and final control elements. (Bulletin B43-1d)

(16) Motor Couplings

A new six-page folder is available from Link-Belt Co. The publication brings together all the pertinent data on the company's motor couplings including the three new features added to the line: a new corrosive duty cover that has exceptional resistance to

acids, alkalines and solvents for applications that subject couplings to chemical attack; a new spacer adapter that speeds and eases maintenance of coupling, driven pumps and compressors by permitting installation with an access gap between shaft ends; and a larger size added to the line that now extends the application range of the couplings of a 2⅝-in. bore size. The MC couplings described in the folder are designed specifically for use as motor couplings for transmitting power to pumps, compressors, generators, speed reducers and similar applications. Packaged components, finished and ready for use, permit "off the shelf" delivery from Link-Belt distributors, zone warehouses and plants. (Folder 2975)

(17) Motor Starters

A complete line of across-the-line motor starters, announced by the Allen-Bradley Co., is described in a new brochure. This line is offered in seven starter sizes—size 00 through size 5—with maximum ratings from 1½ hp, 220 volts; 2 hp, 440–550 volts up through 100 hp, 220 volts; 200 hp, 440–550 volts. The 36-page brochure fully describes this line of starters. Extensively illustrated, it provides detailed information on the many construction, installation, and inspection features. (Bulletin 709)

(18) Castable Refractories

A 24-page booklet describing the physical characteristics of a variety of castable refractories and their application is available from Kaiser Refractories & Chemicals Div. Described within the booklet is a full range of products for use in furnaces ranging in temperature from 700 to 3500 F and with characteristics designed to meet the special conditions imposed on refractories by the demands of furnace operation, atmospheres, fuels and service conditions.

(19) Gas-Powered Lift Trucks

The flexibility of gas power plus the efficiency of electric drive offered in the GLF series lift trucks is discussed in a 16-page booklet published by the Automatic Transportation Co., Division of The Yale & Towne Manufacturing Co. Six pages of breakdown photographs are used to illustrate many of the outstanding features over conventional clutch drive or torque converter type trucks. Driver comfort and safety is shown and how these factors help boost efficiency. Five pages of application photographs of both standard GLF trucks and specials with attachments point out how typical loads are handled in a wide variety of industries and may solve a similar handling problem in your plant. Basic specifications are shown for 13 standard models in the GLF line giving dimensions in an easy-to-read table.

(20) Metal-Clad Switchgear.

An 8-page bulletin giving detailed information on the features, maintenance and simplified installation of General Electric Co.'s outdoor enclosures used with metal-clad switchgear, is now available. Publication details five steps in the eight-hour installation of metal-clad switchgear with protected aisle, and also includes photographs, dimensional drawings, ratings and weight tables of outdoor metal-clad with protected aisle, with common aisle and outdoor metal-clad switchgear breaker compartments. (Bulletin GEA-7190).

(21) Hardfacing Electrodes and Wires

A 44-page brochure has recently been issued by Air Reduction Sales Co., a division of Air Reduction Co., Inc., on hardfacing electrodes and wires. A cross-referenced, pictorial layout—in which all the hardfacing materials are classified and illustrated according to use—makes it convenient to find information in the booklet. The wear protection provided on industrial and construction equipment by these hardfacing alloys is presented in detail. A description of each electrode is presented, along with application data. Over 100 specific equipment parts that benefit from hardfacing are listed in an extensive section, together with the type of wear to which each is subject, and the alloy needed to protect it. (Catalog 1316A)

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IRON & STEEL ENGINEER
1010 EMPIRE BUILDING
PITTSBURGH 22, PA.

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51	B-I-F INDUSTRIES		Coal blending systems
52	BLISS CO., E. W.	CATALOG 40-B	Rolling mills
53	COLUMBUS McKINNON CHAIN DIV., COLUMBUS McKINNON CORP.	BULLETIN 100	Sling chains
54	CONE-DRIVE GEARS, DIV. OF MICHIGAN TOOL CO.	CATALOG 58	Gearmotors
55	ELWELL-PARKER ELECTRIC CO., THE		Electric trucks
56	EUCLID ELECTRIC & MFG. CO., THE	BULLETIN 4290	Magnet controllers
57	GENERAL ELECTRIC CO.	BULLETIN FEA-6706 BULLETIN FEA-7203	Master switches Limit switches
58	HOMESTEAD VALVE MFG. CO.	CATALOG 39-1	Plug valves
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IRON & STEEL ENGINEER

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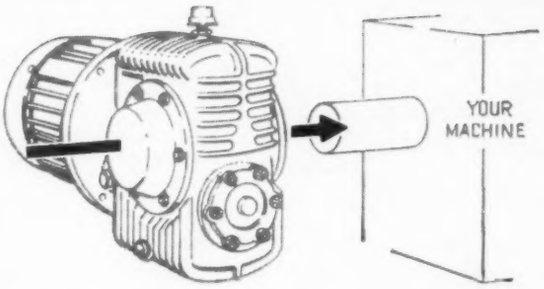
CONE-DRIVE GEARMOTORS for "PLUG-IN" POWER



Hollow-Shaft Speed Reducer-Motor forms complete power transmission package . . .

With the compact, right-angle Cone-Drive gearmotor the machine designer can make use of an integral drive package of nearly any required speed and horsepower. Twenty-seven standard output speeds from 7.3 to 525 RPM (with 1750 RPM motor) are available in models from ¼ to 40 horsepower. Gearmotors can be specified with hollow shaft for mounting in any position, ready to "plug-in". You can use this integrated power package to provide a simple, clean installation on your machine . . . no pulleys, belts, sheaves, bed plates, couplings, etc.

Electric motors are standard "D" flange type with slight shaft modification for driving helical primary reduction gears. Secondary reduction stage is a standard Cone-Drive double-enveloping worm gearset with maximum tooth engagement for greater load carrying capacity in smaller space.

Cone-Drive gearmotors are available for all AGMA service ratings. Call your Cone-Drive representative today or write for catalog #58 for complete specifications.

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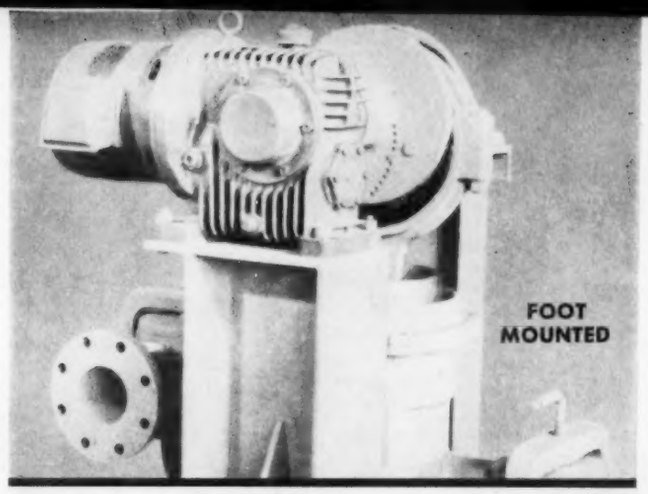
DIVISION MICHIGAN TOOL COMPANY
7171 E. McNichols Road Detroit 12, Michigan Telephone: TWinbrook 1-3111

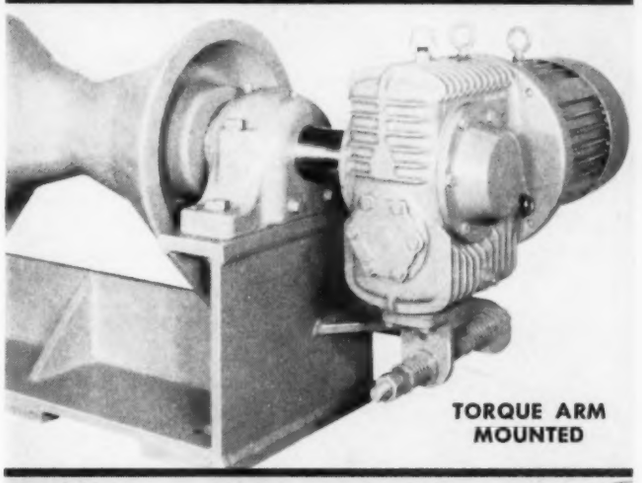
DOUBLE-ENVELOPING WORM GEARSETS

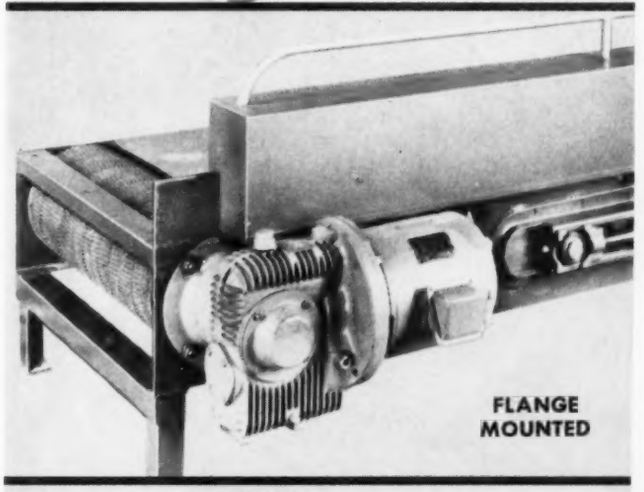
DOUBLE-ENVELOPING WORM GEAR SPEED REDUCERS

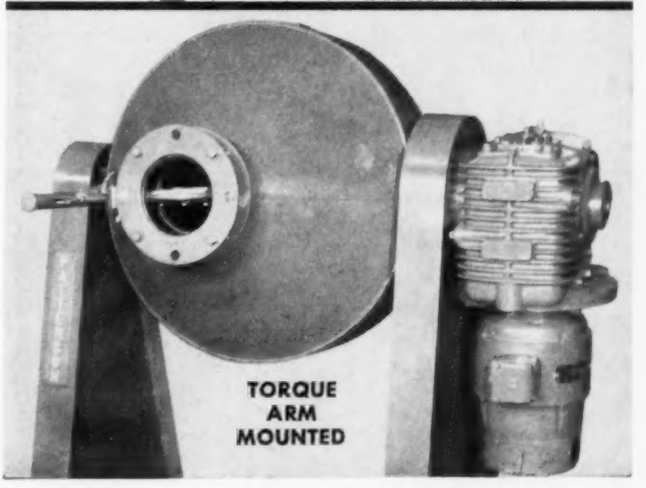
DOUBLE REDUCTION WORM GEAR SPEED REDUCERS

DOUBLE-ENVELOPING RIGHT ANGLE GEARMOTORS









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NEW COLORHO

RHORIZONS System

STOPS RUST AND PROVIDES LASTING BEAUTY

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Apply Rust-Oleum 769 Damp-Proof Red Primer directly over sound, rusted surfaces to STOP RUST and cut maintenance costs

Just scrape and wirebrush to remove rust scale and loose rust—then brush Rust-Oleum 769 Damp-Proof Red Primer right over the remaining rust. Its **specially-processed** fish oil vehicle penetrates rust to bare metal as proved in radioactive tracing studies. You save time and money, as costly surface preparations are usually reduced.

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Distinctive as your own fingerprint.
There are imitations,
but only **one** Rust-Oleum.
Accept no substitute.

PROVED THROUGHOUT INDUSTRY FOR OVER THIRTY-FIVE YEARS

You take the brush! Try a free test sample!

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At no cost or obligation, please send me:

- ☐ New full-color catalog on New Color Horizons System and specialized Rust-Oleum systems. Including color charts and applications.
- ☐ FREE TEST SAMPLE of Rust-Oleum 769 Damp-Proof Red Primer.
- ☐ Please have your representative contact us to discuss a plant survey.

THE U.S. TREASURY SALUTES THE RUBBER INDUSTRY

and its people who buy Savings Bonds and strengthen America's Peace Power

Americans who work in the rubber industry are proud of the rapid strides being made in their field, both in volume and in variety. Automotive rubber products and molded and mechanical rubber goods show constant gains in quality and quantity. Further, the rubber industry has done pioneer work in such novel applications as moving sidewalks and collapsible tanks for liquid storage.

People who work in this 7 billion dollar industry are proud of another thing, too: the help so many thousands of them are giving to America's Peace Power through the purchase of U. S. Savings Bonds. By regular purchases of Shares in America, these patriotic and forward looking people are reinforcing their own security after retirement. By this means they establish reserves for emergencies as well as for long range family projects, like education and home building.

If your company has not, thus far, set up a Payroll Savings Plan, you can start immediately. Just telephone your State Savings Bonds Director and accept the help he is anxious to give you. Or write to Savings Bonds Division, U. S. Treasury Department, Washington, D. C.

Harold E. Kalb is shown here at his work in one of the great manufacturing plants of the rubber industry. Like many thousands of his fellow craftsmen, Mr. Kalb is using his company Payroll Savings Plan to contribute regularly to the Peace Power of his country.

IRON & STEEL ENGINEER

THE U. S. GOVERNMENT DOES NOT PAY FOR THIS ADVERTISEMENT. THE TREASURY DEPARTMENT THANKS, FOR THEIR PATRIOTISM, THE ADVERTISING COUNCIL AND THE DONOR ABOVE.

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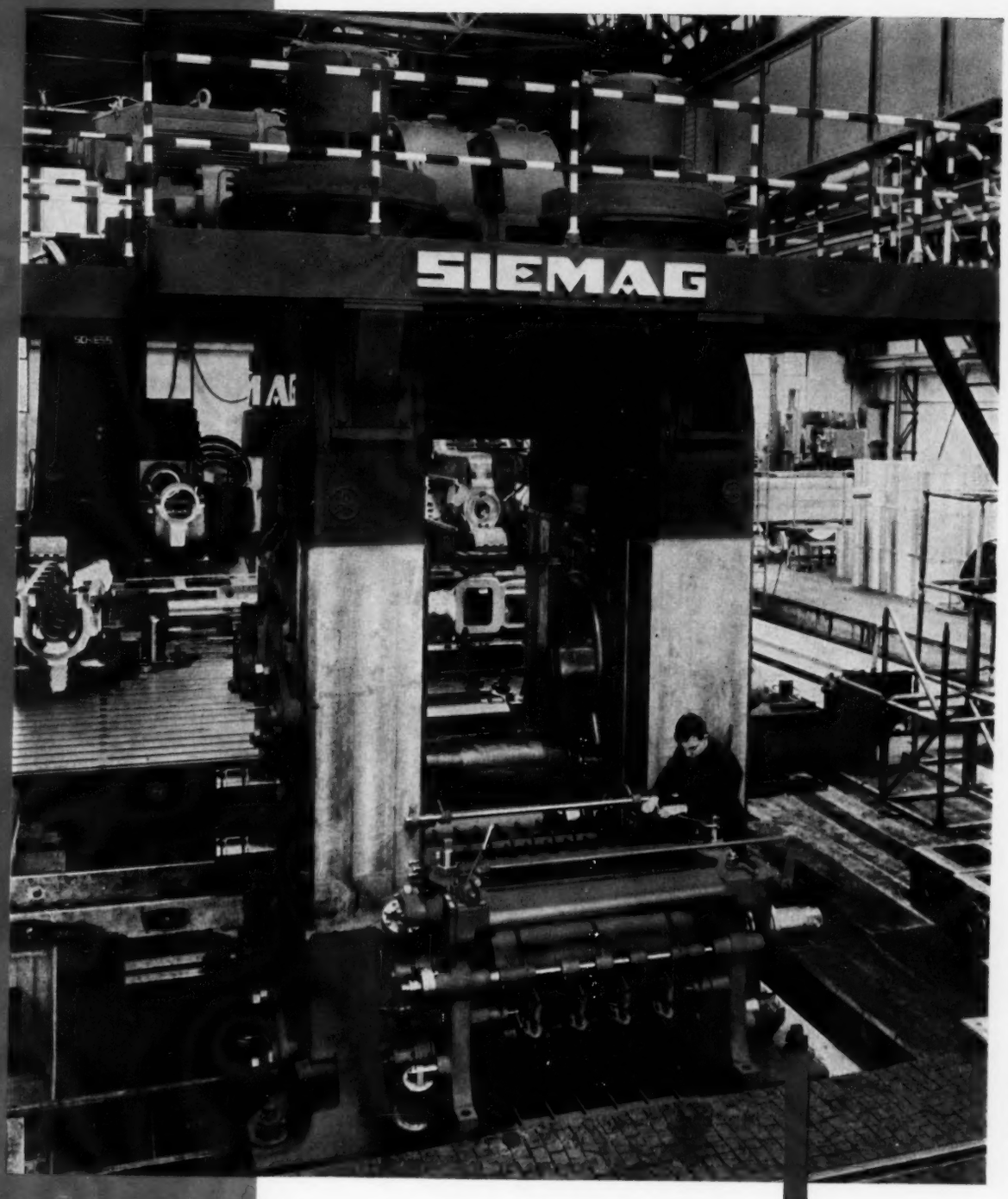
IN ROLLING MILL CONSTRUCTION



AW 60—61

48" 4-Hi Skin Pass Mill
with front and back Tension Rolls
- Workshop Assembly -

Roll Dia. 18"/49"
Rolling Speed 2400 FPM

For high performance
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SIEMAG Rolling Mills

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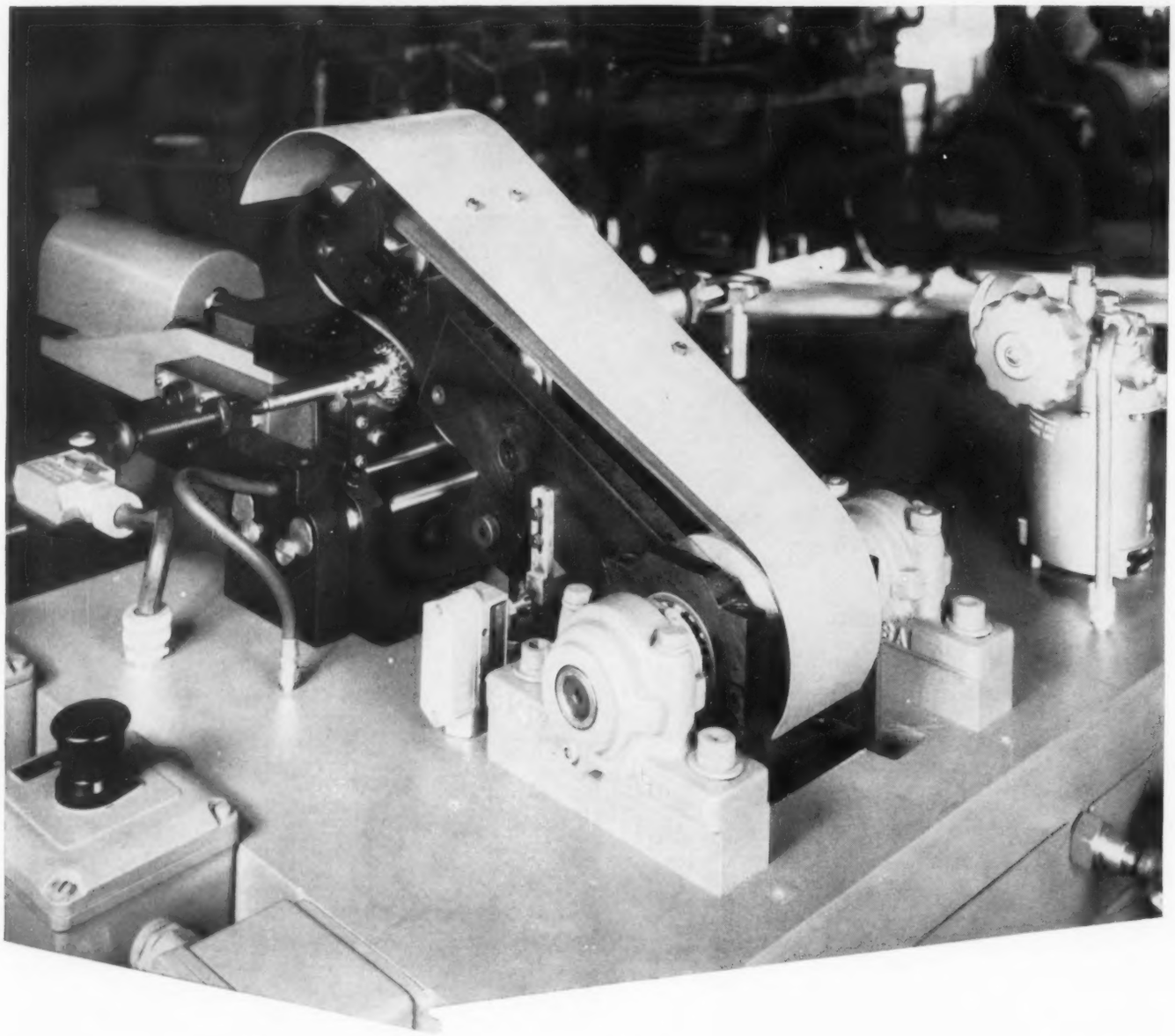

New machine suffered from short bearing life until Bearings, Inc. helped in re-design

The problem was high speed and a shock load condition. Together they spelled trouble for this new commutator turning machine that produces 500 to 700 finished commutators per hour. Our customer asked us to help eliminate the problem of short bearing life due to the impact and speed of the operation.

We helped re-design the machine to use oil mist lubricated pillow blocks on the drive end as well as a bearing with higher load carrying capacities in the driving arm. Since these changes, our customer has had no further trouble with the bearings.

If *you* have a problem regarding bearings, give our nearest branch a call. You'll get the help you want!

Providing bearing service in the North →

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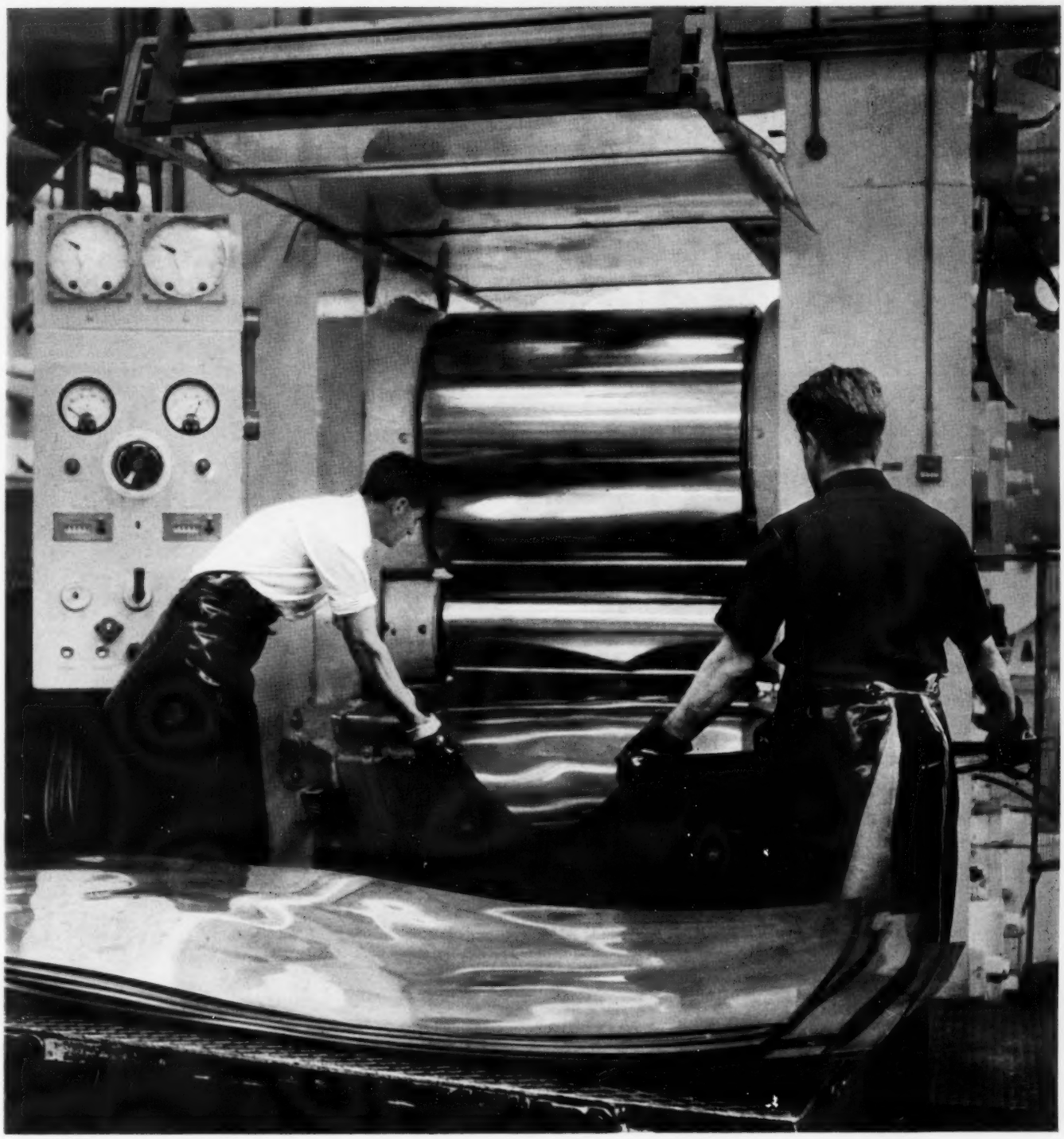


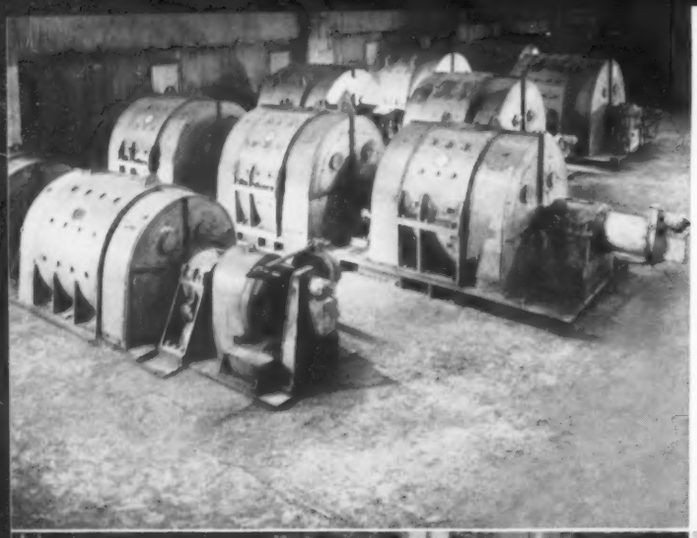
Photograph by courtesy of Henry Wiggin & Co. Ltd.

Firth Brown Forged Steel Rolls for the Cold Production of Sheet and Strip.

FIRTH BROWN

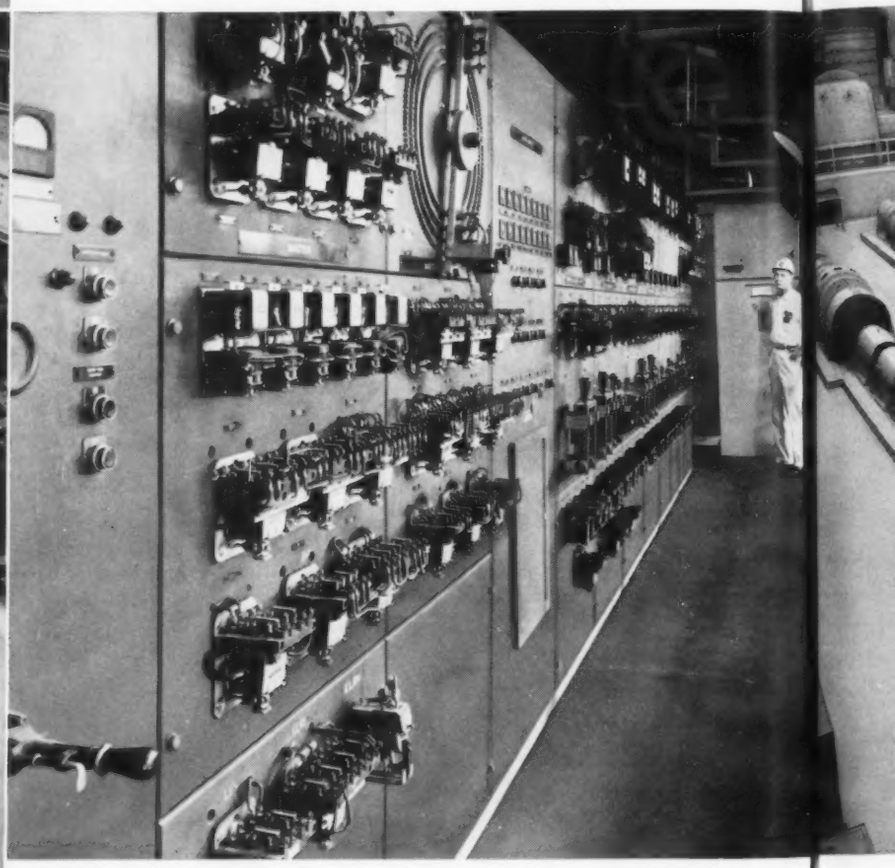
ALLOY STEELMAKERS · FORGEMASTERS · STEEL FOUNDERS · HEAVY ENGINEERS

THOS FIRTH & JOHN BROWN LIMITED · SHEFFIELD · ENGLAND



A-C cooperation limits "changeover" downtime: In 1958, Granite City Steel's four-stand cold strip mill was modernized to increase sheet-gage tonnages by 35%. Downtime for the changeover (from 9600 hp at 2800 fpm to 18,700 hp at 3600 fpm) was three weeks. A-C installed motors, m-g sets and 400-cycle control. Now being constructed are the motors, control, and a feedback automatic gage control for a new 40-in. Sendzimir mill.

Allis-Chalmers powers shearing line: Allis-Chalmers direct-current adjustable-voltage control and direct-current drives provide accurate shearing of sheets at speeds up to 1000 feet per minute. A magnetic piler, incorporated in this line, assures careful handling of sheets.



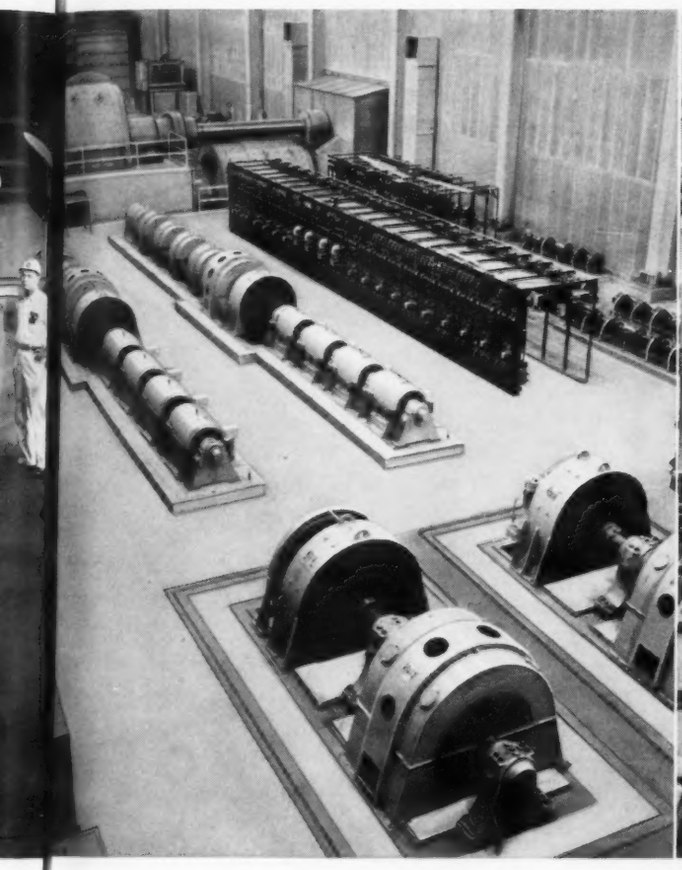
Sixty-eight motors power plating rolls: When this electrolytic tinning line went into operation in 1960, sixty-eight 5-hp Allis-Chalmers totally enclosed, fan-cooled dc gearmotors powered the plating rolls. Additional Allis-Chalmers motors and supporting motor-generator sets provide power throughout the line. Allis-Chalmers motors and supporting variable-voltage motor-generator sets also serve a high-speed continuous annealing line at Granite City Steel Company.

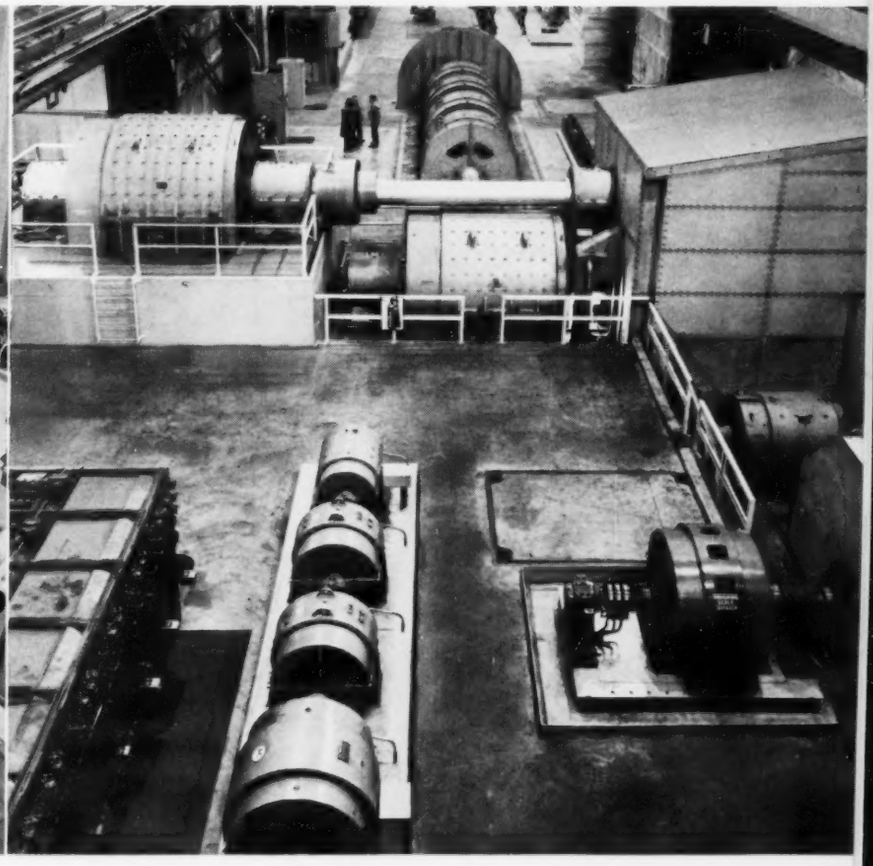
ALLIS-CHALMERS PRODUCTS FOR THE STEEL INDUSTRY: Allis-Chalmers serves the steel industry with motors, m-g sets, engine-generator sets, controls, rectifiers, switchgear, transformers, circuit breakers, steam turbine generators, condensers, compressors, pumps, materials handling equipment, crushers, grinding mills, kilns and screens.

ALLIS-CHALMERS

Pick a process...any mill process...and discover the dynamic Allis-Chalmers leadership in

Power for Steel





Allis-Chalmers power serves blooming mill: Installed in 1953, the 45-in. by 115-in. blooming mill at Granite City Steel operates as a high-lift slabbing mill. It's powered with an Allis-Chalmers 10,000-hp twin drive, 40/80-rpm reversing motor. Additional A-C equipment includes switchgear, direct-current control, constant and variable-voltage m-g sets, and REGULEX exciter sets.

Hot strip mill upgraded: Granite City Steel's hot strip mill has been continuously upgraded to increase tonnage and quality. A four-stand finishing train, installed in 1936, was upgraded in 1941 with the addition of a fifth finishing stand. In 1952, a three-high rougher was replaced with a four-high reversing rougher — horsepower was increased from 3000 hp to 7000 hp plus a 1000-hp edger. Horsepower of the finishing train was later increased by raising bus voltage from 600 to 650 volts. Now, an Allis-Chalmers feedback automatic gage control is being installed to increase quality of strip.

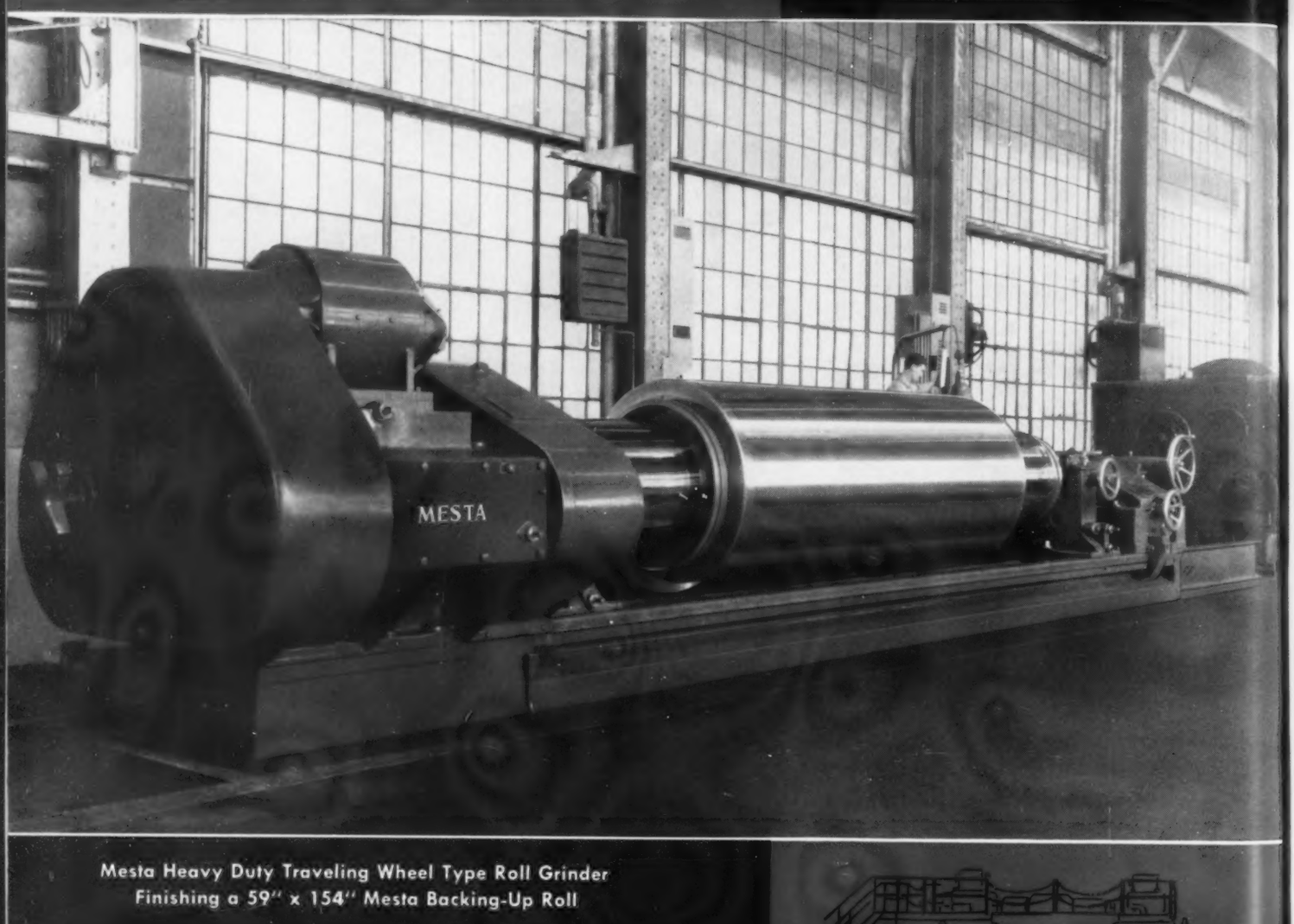
Throughout the mills at Granite City Steel are numerous examples of Allis-Chalmers leadership and experience in power for steel. A-C equipment is used in virtually all operations—rolling mills, processing lines, sintering plant, and power plant. All demonstrate the extra value that is standard with A-C products, systems and services. Allis-Chalmers can also help you serve tomorrow's changing markets profitably. See your A-C representative or write directly to Allis-Chalmers, Industries Group, Milwaukee 1, Wisconsin.

A-1454

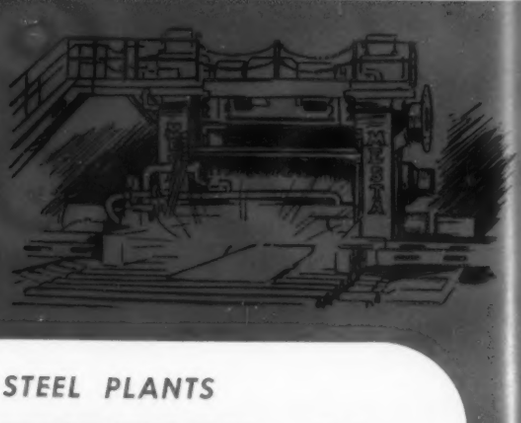
Regulex is an Allis-Chalmers trademark.

Heavy Duty ROLL GRINDERS

Designed and Built by MESTA



Mesta Heavy Duty Traveling Wheel Type Roll Grinder
Finishing a 59" x 154" Mesta Backing-Up Roll



DESIGNERS AND BUILDERS OF COMPLETE STEEL PLANTS

MESTA MACHINE COMPANY · PITTSBURGH, PA.

Personnel News...

A. T. Duff was named assistant to administrative vice president—facilities planning of United States Steel Corp. He succeeds **John A. Hagan** who has resigned. Mr. Duff has been general superintendent since 1957 of the corporation's Irvin Works. With the exception of a three-year period, Mr. Duff has spent his entire U. S. Steel career at Irvin, starting in 1938 as a weigher in the Cold Reduction Department, soon after Irvin began operations. He served successively as foreman of the Tin Finishing Department, assistant superintendent of cold reduction and superintendent of the mill's Galvanizing Department. In 1950, he became superintendent of the 80-in. hot strip mill. Mr. Duff began his three-year absence from Irvin in 1952, when he was transferred to Fairless Works as superintendent of tin finishing. He returned in 1955 as assistant superintendent of the Irvin Works, and in 1957, he was appointed general superintendent, the position from which he has just been promoted.

G. P. Carson has been named general superintendent of Irvin Works, succeeding Mr. Duff. Mr. Carson has been assistant general superintendent at Irvin Works since 1957. Succeeding him as assistant general superintendent will be **Charles D. Kelly,** who will move to the Pittsburgh area from U. S. Steel's Fairless Works, where he has been division superintendent, sheet and tin. Mr. Carson has been with the corporation since 1935, beginning his career at U. S. Steel's Gary Sheet Mill. He was transferred to Irvin Works in 1938, receiving a series of promotions before being named superintendent of cold reduction in 1954. In 1956, he was transferred to the Gary Sheet & Tin Mill as division superintendent of the sheet mill. A year later, he returned to Irvin Works as assistant general superintendent. Mr. Kelly joined U. S. Steel in 1937, starting at the Vandergrift plant of Irvin Works. He moved to Irvin Works in 1938, and became an annealing foreman in 1940. After a series of promotions, he was named assistant superintendent of the cold reduction mill in 1949. Two years later, when Fairless Works was opened, he was appointed superintendent of cold reduction and sheet finishing.

A. T. DUFF

G. P. CARSON

P. C. ELY

D. C. OSBORNE

J. J. TIMBERLAKE

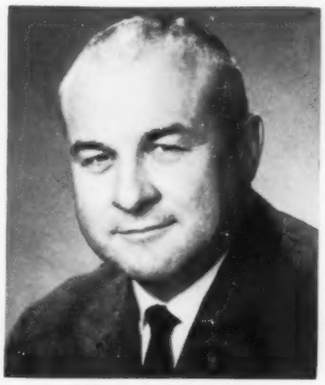
J. G. TOWNSLEY

Paul C. Ely has been appointed general manager—operations for National Tube Division, United States Steel Corp. In this newly-created position, Mr. Ely will be responsible for the manufacturing activities of National Tube's six plants. He was formerly assistant vice president—operations, tubing specialties. At the same time was announced the retirement of **Ralph M. Overton** who has been assistant vice president—operations. Mr. Ely has spent his entire business career with National Tube. He joined National Tube at its Pittsburgh headquarters in 1927 as a metallurgist. In 1930, he was transferred to National Works in McKeesport and has held various operating positions in National Tube both at McKeesport and Lorain, Ohio. In 1954, he was named general superintendent of the Division's Gary, Ind., Works, which position he held until he was transferred to Pittsburgh in 1959. Mr. Overton joined National Tube in 1924. He held various engineering and operating positions in National Tube, becoming general superintendent of National Works, McKeesport, Pa., in 1942. He was transferred to the former United States Steel Corp. of Delaware to the staff of vice president of operations and engineering in 1946, returning to National Tube in 1948 as assistant vice president of operations.

Ora E. Clark, general superintendent of Armco Steel Corp.'s Middletown, Ohio, plant, will retire June 1, after 34 years of service with the company. **Donald C.**

H. V. GUMMA

D. W. YARBERRY



W. O. FITZKE

HARRY GEISELMAN

Osborne, presently assistant general superintendent of maintenance and services, will succeed him as general superintendent. **John J. Timberlake** will become assistant general superintendent of maintenance and services. He is now superintendent of assigned maintenance. **James G. Townsley,** now assistant superintendent of assigned maintenance, will be promoted to superintendent of assigned maintenance.

Mr. Clark joined Armco's Hamilton, Ohio, plant in 1927 as blast furnace superintendent. In 1947 he became assistant general superintendent of the Hamilton plant and general superintendent the following year. He moved to the Middletown Works in 1951 as general superintendent of blast furnace operations and was promoted to general superintendent of the plant in 1956. Mr. Osborne joined Armco in 1933. He became a combustion foreman in the Processing Department in 1936. He was named assistant to the superintendent of cold strip processing in 1941, and superintendent in 1946. In 1950 he was made superintendent of the East Processing Department. He was promoted to assistant to general superintendent in 1956, and in 1957 became assistant general superintendent of rolling and processing. Mr. Timberlake joined Armco in 1935. After serving as an electrical engineer, he was named a general foreman in the Maintenance Department in 1944. He was promoted to assistant superintendent of the department in 1948, and superintendent of assigned maintenance in 1959. Mr. Townsley started with Armco in 1947 and after several special assignments he was named an assistant foreman in assigned maintenance in 1950. He became a turn foreman in the department in 1953 and general foreman in 1957. He advanced to assistant superintendent of assigned maintenance earlier this year.

Harold V. Gumma has been appointed superintendent of the rolling and finishing departments at The Colorado Fuel and Iron Corp.'s Pueblo plant, succeeding **Victor N. Johnson,** who has retired. Mr. Gumma has served as assistant superintendent of the rolling and finishing departments since 1951. Previously he acted as general foreman of the rolling mills, foreman in the rail mill, senior industrial engineer, and turn foreman in the forge plant. He joined CF & I in 1937 in the Inspection Department of CF & I's Pueblo plant.

Delbert W. Yarberry succeeds Mr. Gumma as assistant superintendent of the rolling and finishing departments at Pueblo. Mr. Yarberry has been serving as division superintendent for the rail mill, 40-in. mill, rod mill and conditioning unit since 1953. Previously he had served as general foreman of the rolling mills, general foreman of the rail mill finishing, general foreman of the forge plant, turn foreman of the forge plant, and in the inspection department. He joined CF & I in 1928 in the Pueblo plant's Yard Department. Mr. Johnson became superintendent of the rolling and finishing departments in 1951, having served as assistant superintendent since 1945. Previously, he was in charge of the 40-, 12-, 20- and 25-in. mills, after acting as superintendent of the garrett rod mill and of the 10-in. mill since 1919.

William O. Fitzke has been named superintendent of the Mechanical Department at Republic Steel Corp.'s Canton, Ohio, plant. He succeeds **Paul L. Walter,** who retired April 1, after 49 years of service with Republic and predecessor companies in Canton. Mr. Fitzke joined Republic at Canton in 1940, as a utilities engineer. He later served as assistant steam engineer and steam engineer, before being named assistant superintendent of the Mechanical Department in 1948. Mr. Walter worked as a civil engineer during the construction of the Canton plant's coke ovens and blast furnace in 1912. Upon the formation of Republic Steel in 1930, he became assistant superintendent of power and later superintendent. He has been superintendent of the Mechanical Department since 1939.

Harry Geiselman succeeds Mr. Fitzke as assistant superintendent of the Mechanical Department. A veteran of 28 years with Republic in Canton, Mr. Geiselman started at the Canton plant in 1933 as a repair helper in the Power Department. He served in numerous other capacities in this department before being appointed general foreman of the Mechanical Department in 1953. He has served as general foreman of the blast furnace and coke plant since 1957.

John A. Hagan, formerly assistant to the administrative vice president—facilities planning, U. S. Steel Corp., has joined Kopper Co., Inc., as representative in connection with a new steel mill project in Turkey. Mr. Hagan will become a vice president in Koppers Engineering and Construction Division, and also will serve as a member of the board of directors of the Eregli Demir Ve Celik Fabrikalari T.A.S. (Eregli Iron and Steel Works). Mr. Hagan started with U. S. Steel in 1930 as an industrial engineer at the Homestead Steel Works, and was promoted to chief industrial engineer

LIFT A COIL, SCRAP, OR LADLE

40/15 ton, 120 ft. span Yuba Bedford Crane in sheet mill coil storage area at U.S. Steel's Gary Sheet and Tin Mill, Gary, Indiana.

. . . JOBS FOR YUBA BEDFORD CRANES

Move steel coils into storage, out for shipment – position and dump scrap – lift and "spot" huge ladles of molten steel... these are the jobs Yuba Bedford Cranes are designed to perform effortlessly, dependably and continuously.

Bedford Cranes have done the difficult and the heavy work for steel makers for over half a century. During periods of high plant capacity, Bedford Cranes work ceaselessly shift after shift, with only routine maintenance. During periods of reduced capacity, these same cranes, with only slight modification, have been assigned to handle a variety of load ranges and services.

Whether you're modernizing or expanding it will pay you to check out savings that may be realized from the installation of Yuba Bedford Cranes. Full information on request.

Yuba designs and builds all types of cranes, including bridge, unloading and material handling, gantry and semi-gantry, floating and jib cranes. Also derricks, hoists, and launching towers for defense ordnance.

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J. A. HAGAN

T. A. BEDFORD

C. G. BIGELOW, JR.

N. E. PRICE

for Carnegie Steel Co. in 1933. He moved to Carnegie's Youngstown District Works in 1940 as superintendent of production and cost planning. In 1945, he was named general manager of production planning of Carnegie Illinois Steel. Five years later he became assistant general superintendent of U. S. Steel's Youngstown District. In 1951, he returned to Homestead as general superintendent. In 1958 Mr. Hagan was assigned to his latest position in which he represented U. S. Steel's operating management in the long-range planning of manufacturing facilities for all U.S.S. operations.

T. A. Bedford has been elected president and director of Henry J. Kaiser Co. (Canada) Ltd. He has been vice-president in charge of engineering and construction project development for Kaiser Engineers since 1955. Mr. Bedford joined the Kaiser organization during construction on Hoover Dam in 1932. Since 1955, he has been responsible for developing a wide variety of engineering and construction projects for Kaiser Engineers in industrial fields: steel, nuclear, hydroelectric, steam power, petroleum, chemical, mining and minerals.

C. Glen Bigelow, Jr., has been elected vice president—research, Selas Corporation of America. He joined Selas in 1958 as director of research, coming from American Machine and Foundry Co. where he had served as technical director of the general engineering laboratories, and new products secretary. He was also previously associated with Loftus Engineering Co., as assistant chief engineer, and with U. S. Gypsum Co. as research engineer.

Norman E. Price has been appointed assistant superintendent of the Plant Engineering Department at Kaiser Steel Corp. He came to Kaiser Steel in 1954 as rolling mills engineer. In 1955, he was appointed staff engineer, rolling mills, and then advanced to supervisor of project engineering the same year. In 1957 he was named supervisor of design and project engineering, the responsibility he held prior to his present appointment.

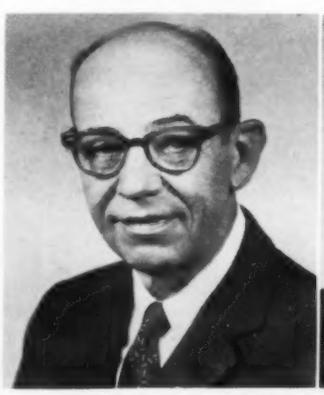
Winfield R. Scott, a veteran of 34 years with Weirton Steel Co., division of National Steel Corp., has been named assistant to the general superintendent in the Operations Department. He advances from the position of cost analyst in the Operations Department. Mr. Scott began his employment with Weirton in 1927 in the Strip Steel Shipping Department. In 1936 he was named assistant chief clerk in the Strip Steel Department, holding that position until 1952 when he transferred to the company's Cost Department. In 1954 he was appointed cost analyst in the Operations Department.

John E. Holt has been appointed assistant to the vice president—operations, production with Crucible Steel Co. of America. He was formerly division superintendent—flat rolled products at the company's Midland, Pa., Works. Mr. Holt joined Crucible in 1943 as assistant manager of the D.P.C. Department at the Midland plant. He became superintendent of the Forge Stock Department, and in 1956 he was named superintendent of the 24-in. bar mill. He was promoted to assistant division superintendent of the Flat Rolled Products Division in 1958 and division superintendent in 1959. Before coming to Crucible, Mr. Holt was employed by Phoenix Steel Corp. in Phoenixville, Pa.

Roy P. Williamson was named vice president of international sales, a newly organized division of The Morgan Engineering Co. Mr. Williamson has been affiliated with the company since 1955 serving in the capacity of vice president—sales. Prior to joining Morgan, Mr. Williamson served in various sales capacities with Industrial Brownhoist Corp., Manning, Maxwell & Moore (Shaw-Box Division), Gustin Bacon Manufacturing Co. and The Buda Co.

A. Fred Morris, Jr., succeeds Mr. Williamson as vice president—sales. Mr. Morris has been affiliated with Morgan since 1938. He worked in the engineering and estimating departments until 1946 when he was transferred to the Sales Department. In 1959, he was ele-

R. P. WILLIAMSON



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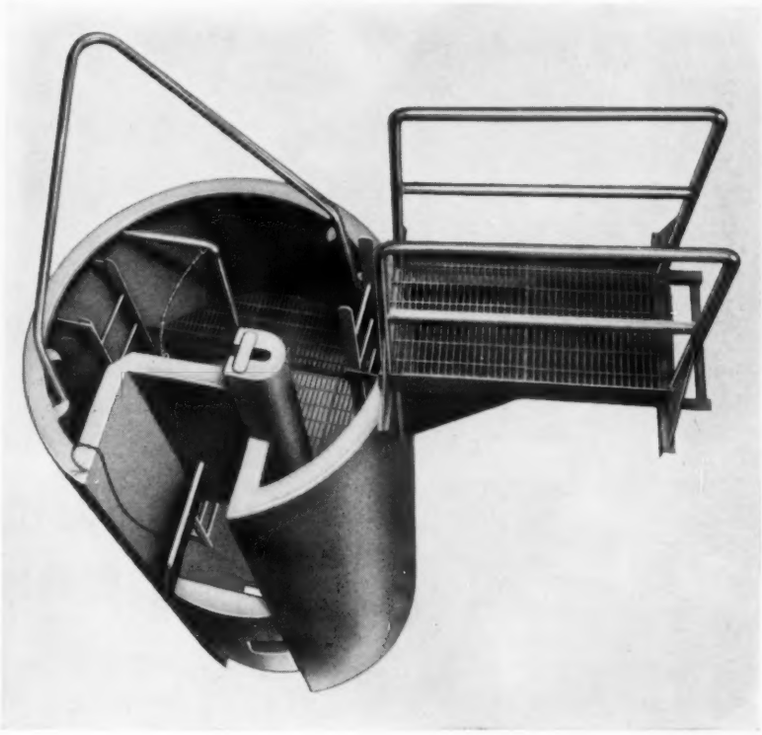

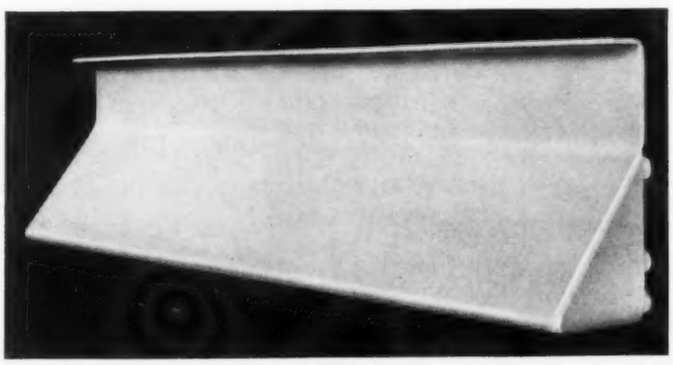

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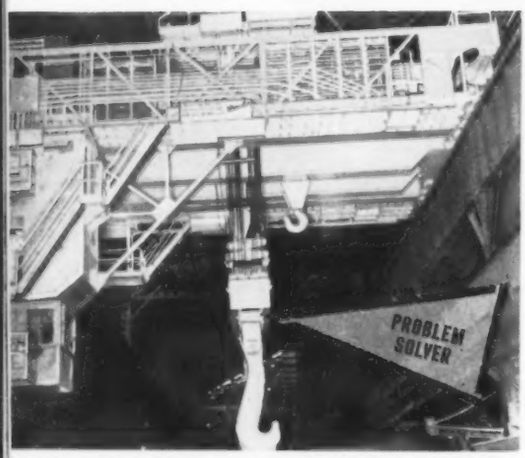

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Standard crane designs of 30 years ago can't solve materials handling problems for today's steel mills. Problems unique to each mill demand cranes especially engineered for the job.

That is why these ten leading steel companies developed their own crane specifications — or chose modern AISE standards. Each awarded the job of constructing the crane to Shaw-Box.

Shaw-Box produces cranes of any type and capacity to AISE standards or your own. Your particular materials handling problems come first. We are not bound by traditional concepts of design. The crane you want is developed for top efficiency, easy maintenance, power economy, and complete safety.

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S. K. TOWSON, JR.

W. A. MEDDICK

vated to sales manager. He has been a member of the board of directors since 1954.

Sheldon K. Towson, Jr., has been elected president and chief executive officer of The Elwell-Parker Electric Co., and **W. A. Meddick** has been elevated to the post of chairman of the board. Mr. Towson was formerly vice president and general manager. He joined the company in 1956 as assistant to the president, and was named to the post of vice president in 1958. He was previously with Allegheny Ludlum Steel Corp. Mr. Meddick, a 25-year veteran of Elwell-Parker, was named president in 1958.

James P. Scanlon has been named assistant superintendent of The Youngstown Sheet and Tube Co.'s Open Hearth Department at the Brier Hill Works. Formerly a turn foreman, he takes the position left vacant by the promotion of **Thomas A. Cleary, Jr.,** now assistant general superintendent of flat rolled and tubular products in the company's Youngstown District. Mr. Scanlon has been with the company for 22 years. Starting as a millwright helper, he advanced through several positions in the Open Hearth Department, becoming a junior melter and then turn foreman.

H. Edwin Berger has been named superintendent of metallurgical engineering at Kaiser Steel Corp.'s Fontana plant. He joined Kaiser Steel in 1953 as assistant chief inspector, rolling mills. In 1954, he advanced to chief inspector, primary mill and then metallurgical engineer. He was transferred to Oakland in 1956 to become resident metallurgical engineer and returned to Fontana three years later as senior metallurgical engineer, the position he held until his present appointment. Mr. Berger was employed by United States Steel Corp. from 1937 to 1953. He started as a metallurgical observer at Duquesne Works, advancing through engineering and production responsibilities to become assistant superintendent of rolling.

William F. Hopkins has been appointed supervisor production planning of Jones & Laughlin Steel Corp.'s Stainless and Strip Division, Detroit, Mich. At the same time, **James D. Dickson** was named coordinator, division inventory control. Mr. Hopkins has been assistant production planning manager of the Stainless and Strip Division since 1957. He joined Rotary Electric Steel Co. in 1940 as an inspector, and remained with the company when it became a division of J&L in 1957. Mr. Dickson joined J&L in 1957 as a production trainee

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in hardened stainless steel

in stainless steel with tungsten carbide orifice tips

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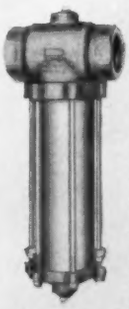

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in Pittsburgh. He was named assistant to the vice president of production during the same year.

David G. Yorke has been appointed as technical director of the Roll Manufacturers Institute. He succeeds **Thomas L. Kablach**, who resigned January 31.

G. Rhoads Casey has resigned as president of the Treadwell Engineering Co., after 22 years in the post. He is succeeded by **Francis R. Curry**. Mr. Casey, with the firm for 50 years, will continue as a director and consultant. **Hazen J. Leaver,** vice president—operations, has been appointed general manager.

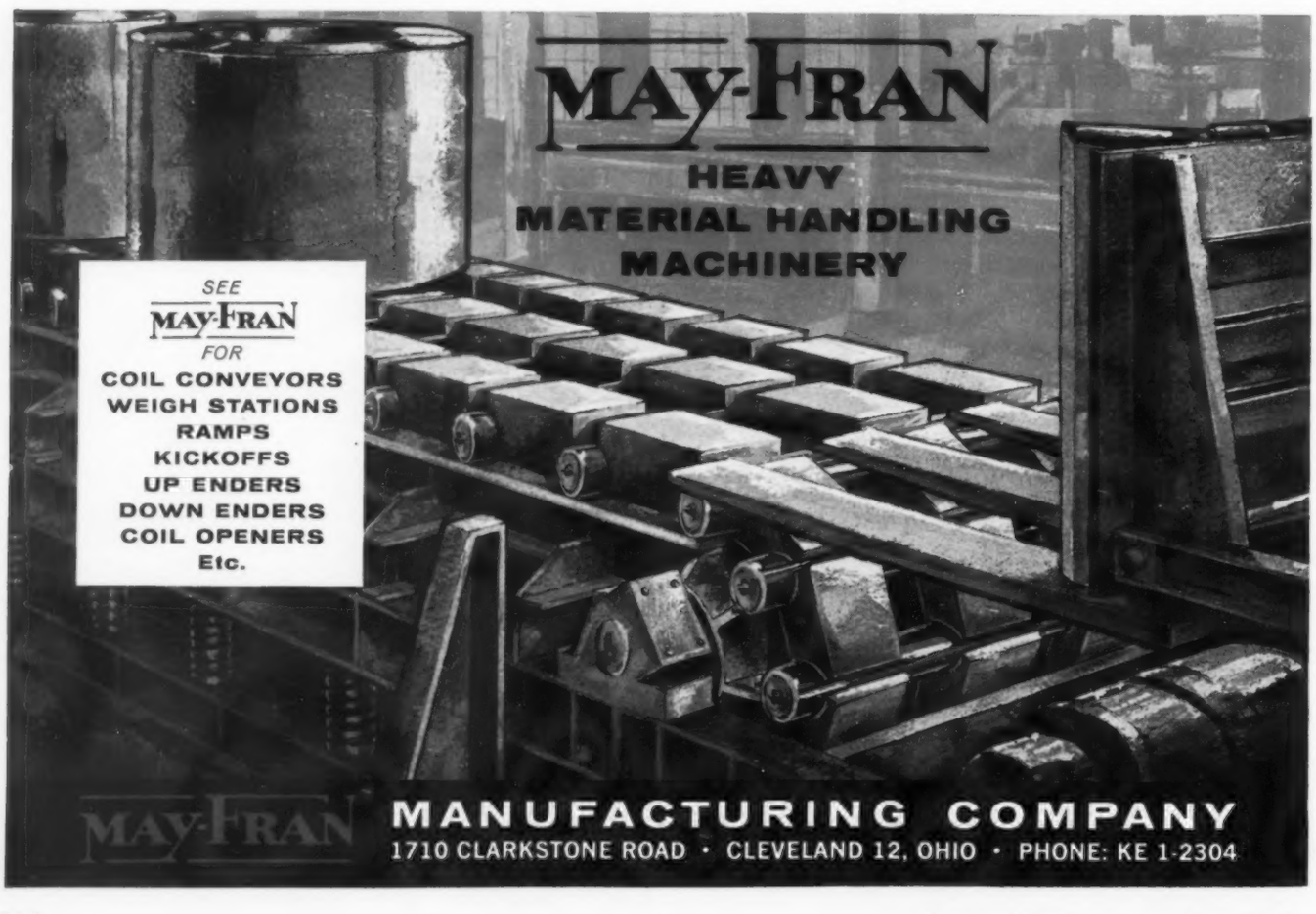
William Sherwood has been appointed project engineer at the Rolling Mill Division of the E. W. Bliss Co. in Salem, Ohio. He was previously a design leader in the Engineering Department. He has been with the division since 1946.

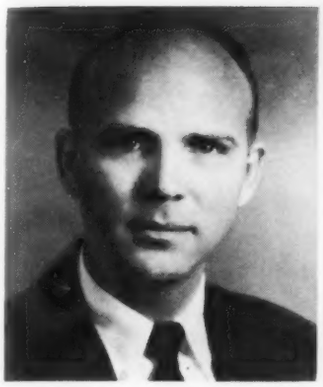
J. J. Offutt has been elected to A. P. Green Fire Brick Co.'s board of directors. Mr. Offutt, vice president and general manager of the company has been connected with the Green organization for over 30 years. In 1946, he was appointed general manager of the A. P. Green Fire Brick Co., Ltd., Toronto, Canada. In 1954 he returned to the home offices in Mexico, Mo., taking over various duties in connection with corporate matters. In 1958 he was appointed vice president and director of sales, and last year became general manager.

George R. Brown has been appointed manager of metal rolling industry sales and **William E. Miller,** manager of metal rolling application engineering, of General Electric Co.'s newly-created System Sales and Engineering Operation. Mr. Brown joined the company's test program in 1948. After various company assignments including steel industry sales for International General Electric Co., he was named manager of steel industry sales for the apparatus sales division in 1953, a position he held until his recent appointment. Mr. Miller joined General Electric's test program in 1939, and received various assignments in the Industry Control and Large Motor and Generator Departments. In 1946, he became an application engineer in the metal rolling and processing industries area.

Walter C. Ibele has been named assistant superintendent of The Youngstown Sheet and Tube Co.'s seamless tube mill Finishing Department at Campbell Works. He succeeds **Winston A. Schoenberger,** who has joined the Company's Continental-Emsco Division at Houston, Tex. Mr. Ibele has been with the company since 1956 when he became a trainee in the Metallurgical Department. He was promoted to assistant metallurgist in the tube mill, then became process engineer in the Seamless Tube Department, and later made general foreman of seamless tube finishing.

J. Russell Britt has been promoted to director of research and development for the Granite City Steel Co. He will be responsible for the development of new flat rolled steel products and the improvement of existing products. He had been director of Granite City's Department of Metallurgy and Inspection. He





P. J. BERG (left)
J. H. PORTEUS (center)
MILTON DEANER (right)

joined the company in 1939, and became assistant to the director of the Department of Metallurgy and Inspection in 1945, and director of the department in 1954.

Philip J. Berg has been named manager—sales and development for the Engineering and Construction Department of Dravo Corp.'s Machinery Division. **J. H. Porteus** has been appointed chief development engineer—ore processing. Mr. Berg joined Dravo in 1946 as a project engineer in the Engineering and Construction Department. He served as a field engineer, a sales engineer and district manager of the Detroit sales office before becoming manager of general construction sales in 1956. Mr. Porteus was principal engineer for Jackson & Moreland, consulting engineers, before joining Dravo in 1951 as assistant chief design engineer of the Machinery Division.

Milton Deaner has been named assistant sales manager of Arthur G. McKee & Co.'s Metals Division. He joined McKee in 1952 as a service engineer in the Metals Division and became a sales engineer three years ago. Prior to joining McKee, he held operating positions with the Blast Furnace Department of United States Steel Corp. at Homestead, Pa.

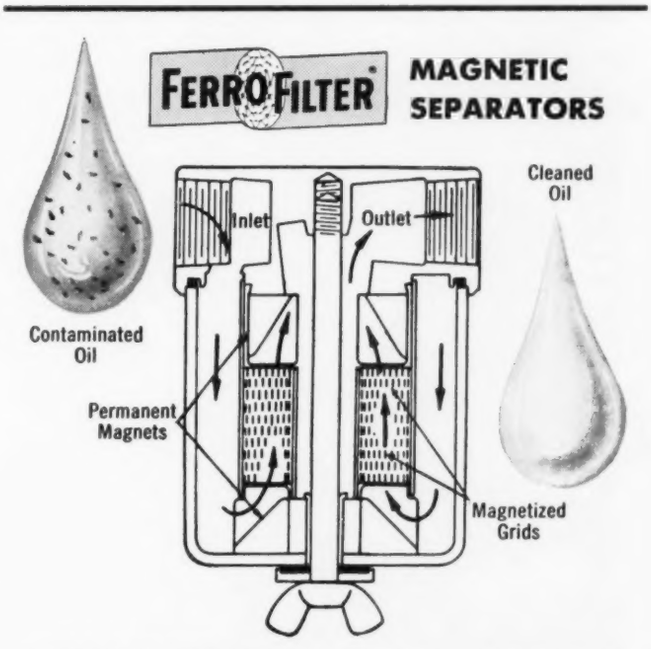
James E. Tredennick has been appointed to the new position of superintendent of inspection at Kaiser Steel Corp. Fontana plant. He came to Kaiser Steel in 1951 as plant metallurgist. In 1953 he was appointed division metallurgist. He has held the position of division metallurgist, iron and steel, for the past eight years. He was employed for 15 years by Bethlehem Steel Co. in Johnstown, Pa., starting as a trainee. He held positions of shift supervisor, observer foreman, and then became division metallurgist, open hearth, primary and plate mills.

T. R. ("**Ted**") **Eberwine** has been elected vice president of James Campbell Smith, Inc., and Correct-Air Corp. Besides heading his own manufacturing company, he has served in various managerial capacities with leading manufacturers of air conditioning products in both engineering and sales.

Daniel H. Schultz, senior vice president and a director of both Leeds & Northrup Co. and of Leeds & Northrup, Canada, Ltd., has been elected president of the Canadian subsidiary. He will succeed **J. William Robinson,** who will devote full attention to his new position as joint managing director of Leeds & Northrup Ltd., Birmingham, England. Mr. Robinson will continue as vice president of the parent company, and as a member of the board of the Canadian subsidiary.

Roy M. Casper has been appointed general manager, Power Equipment Division, Allis-Chalmers Manufacturing Co. He succeeds **J. W. McMullen,** who has retired after 45 years with the company. Mr. Casper, who is a vice president of the company, has been general manager, Atomic Energy Division since 1957.

Orval W. Riggs has been appointed manager of instrument and control product sales for Republic Flow Meters Co., subsidiary of Rockwell Manufacturing Co. Mr. Riggs will also be responsible for product sales for Republic Flow Meters Canada Ltd. Prior to his recent appointment, Mr. Riggs was headquarters sales administration manager for Republic. He joined the company in 1956.



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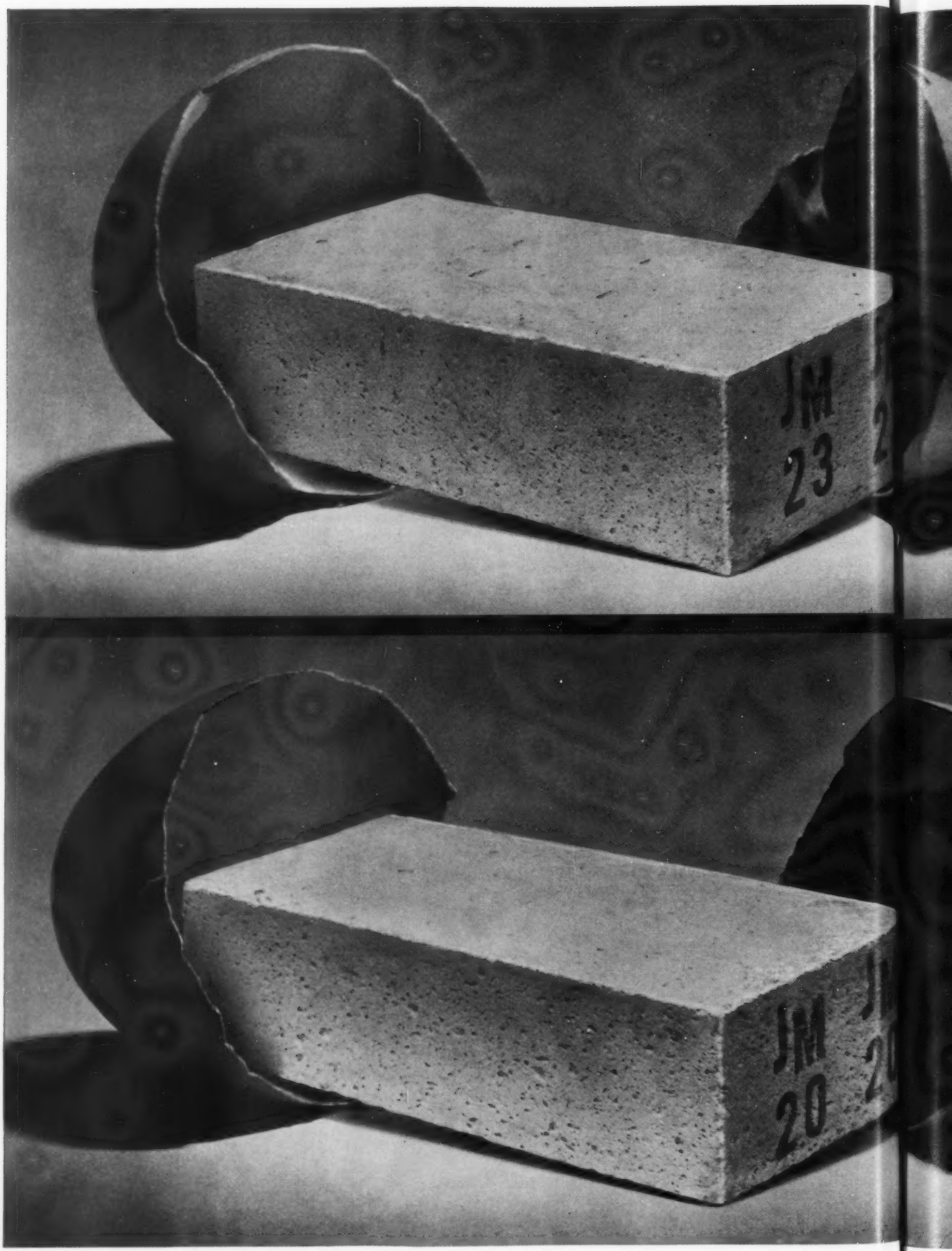
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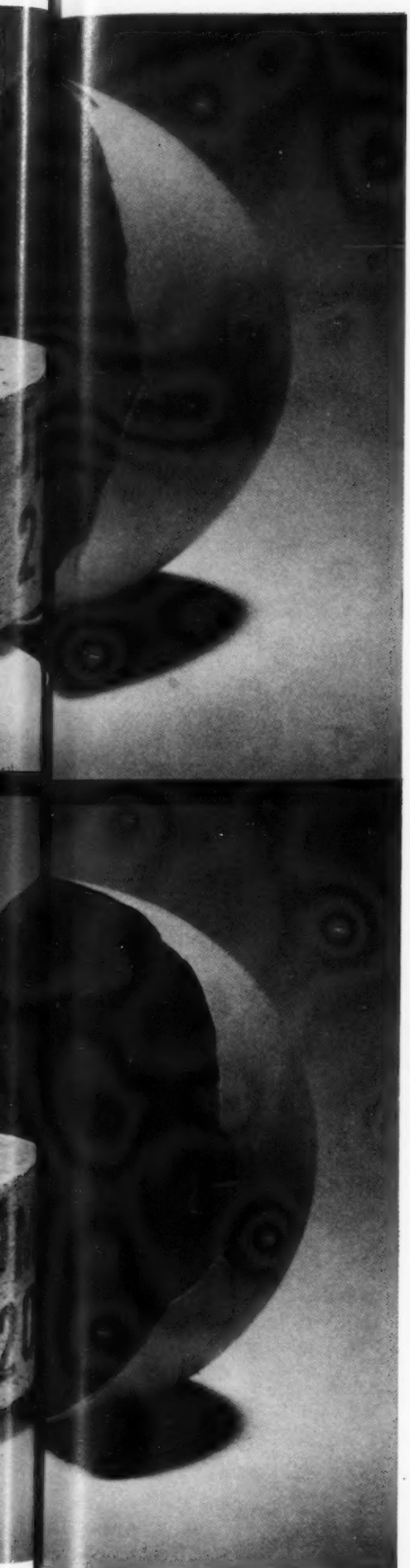

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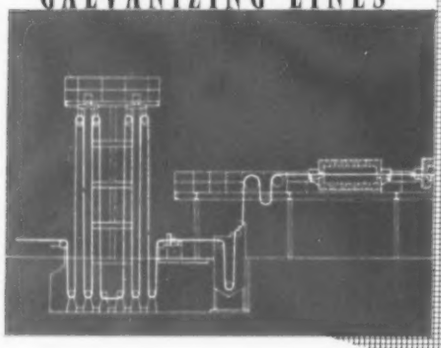

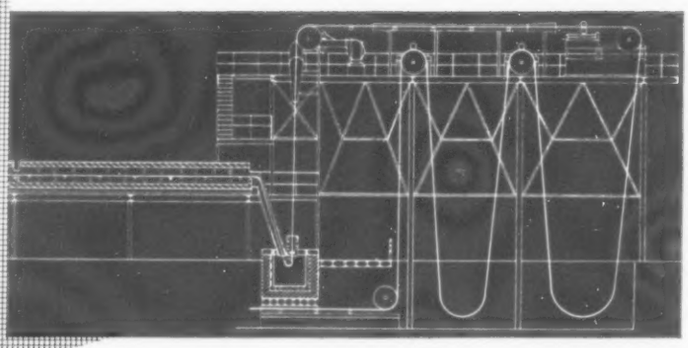

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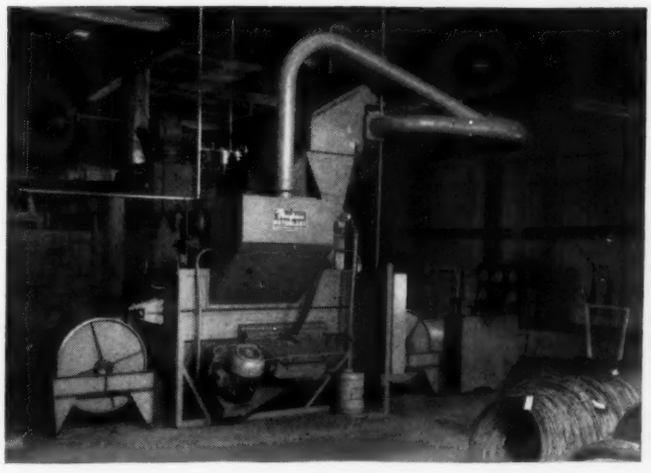

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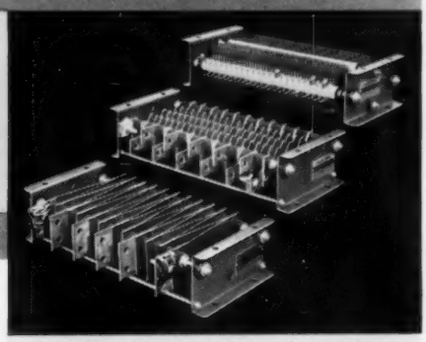

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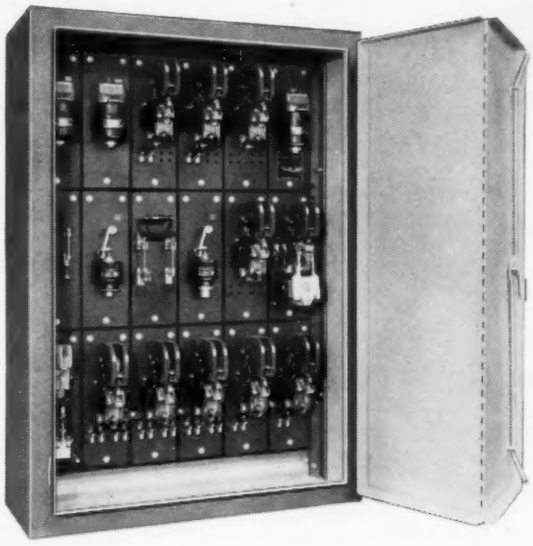
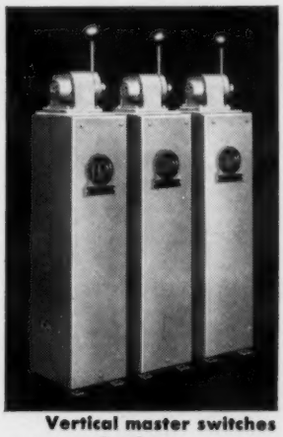
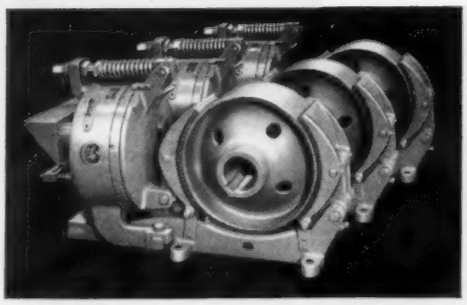
DC controllers are simple to maintain, provide pinpoint accuracy and safe operation.

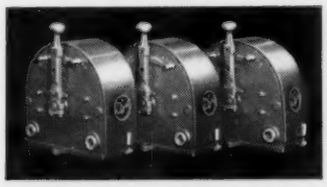




Vertical master switches require little mounting space. Short throw reduces operator fatigue.



Long-life brakes give high-speed performance, have 100% lubrication so that dirt can be flushed out.



CM master switches have short throw of operating handle and narrow width for close grouping.

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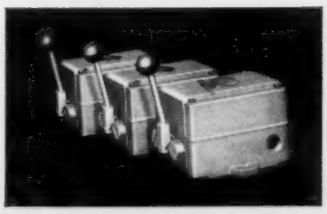

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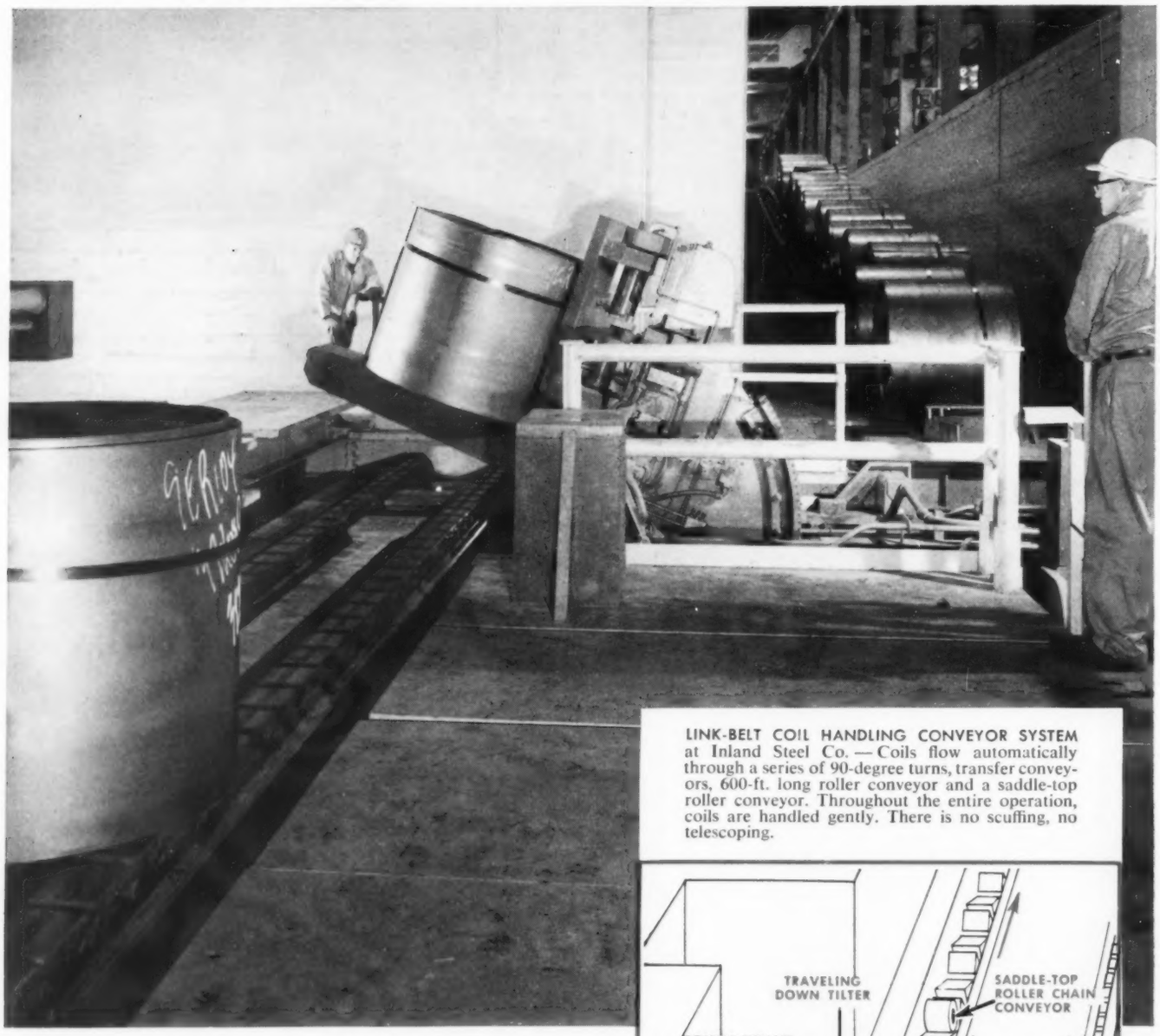
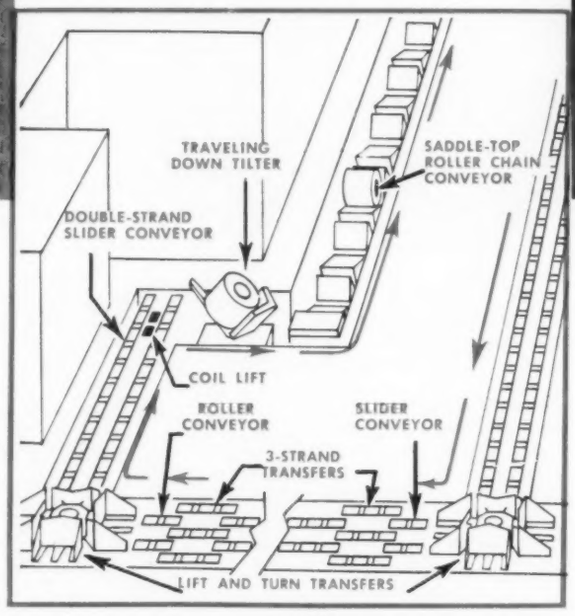
3880

15-ton loads are "run-of-the-mill"



LINK-BELT COIL HANDLING CONVEYOR SYSTEM at Inland Steel Co. — Coils flow automatically through a series of 90-degree turns, transfer conveyors, 600-ft. long roller conveyor and a saddle-top roller conveyor. Throughout the entire operation, coils are handled gently. There is no scuffing, no telescoping.



LINK-BELT coil conveyors take on a tough handling job for Inland Steel

Putting these heavyweights through the mill without damage calls for sure, delicate handling. It's a difficult job performed with precision and safety on Link-Belt conveyors. Coils weighing 15 tons each move automatically from coiler to pickling line.

All through industry, Link-Belt is advancing materials handling to match the pace of production technology. In steel mills throughout the country, Link-Belt conveyors, processing and power transmission machinery—plus expert engineering—are helping to cut costs and improve plant output. For complete details on single units or complete systems, contact your nearest Link-Belt office. Ask for Book 2764. 15,390

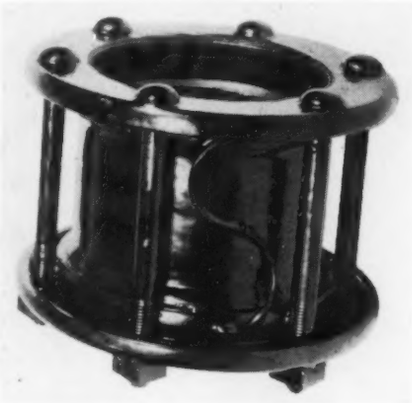
LINK-BELT

One source . . . one responsibility for materials handling, processing and power transmission equipment

Equipment News...

COATED COUPLING

△ A coupling with a permanent coating which will not disbond in any weather has been announced by Dresser Manufacturing Division, Dresser Industries, Inc. This novel coating, "Stab-Clad" Style 123, has



the unusual feature of being concealed by a useful but expendable outer shell, while independently assuring 99.2 per cent protection against corrosion. Electrical continuity of the coupling achieved through a special bonding device assures cathodic protection against corrosion, and installation procedures are said to be easy.

The coupling is designed so that it requires no disassembly and reassembly for installation in the field. Pipe ends to be connected can be simply "stabbed" into the ends of the coupling. Thus, the carefully applied factory-coating is not disturbed in field application of the product.

In a fully preassembled and coated coupling, the bolts must, of course, be capable of being tightened. During the factory assembly process, the bolt threads are specially processed with a release agent obtained as a constituent of coal tar itself. This is ideal for the purpose as it is fully compatible with coal tar, and yet provides release so nuts turn freely for proper field installation.

In initial field-testing, engineers found that when the ground temperature changed 25 deg, a steel, all-welded pipe was forced to move with respect to the ground. They further found that whenever there was a bend or curvature in the pipe, endwise motion was accumulated, and the coating on the pipe was rubbed by the soil. In time, ordinary coatings were rubbed enough to be penetrated by small stones. And careful application of high quality, wrapped coating on the pipe was to no avail. This problem was nonexistent where Dresser couplings had been used; the so-called "soil stress" due to changes in ground temperature was substantially eliminated as the couplings absorbed and distributed the motion so that it was not significant.

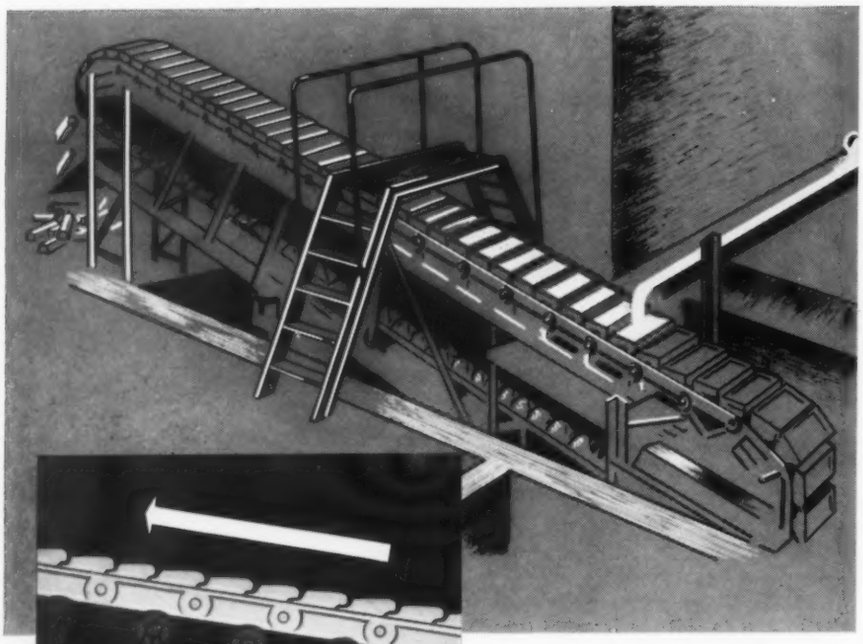
An experiment with 400 ft of all-welded pipeline was conducted, with bends at each end of the line, and it was found to contract $\frac{3}{4}$ in. when the temperature dropped 25 deg. The $\frac{3}{4}$-in. movement was divided between the bends, each moving $\frac{3}{8}$ in. with respect to the soil. The unit movement or increment of movement per foot proportionately decreased to zero at the center of the 400-ft section, and the greatest damage due to rubbing against the soil was at the ends.

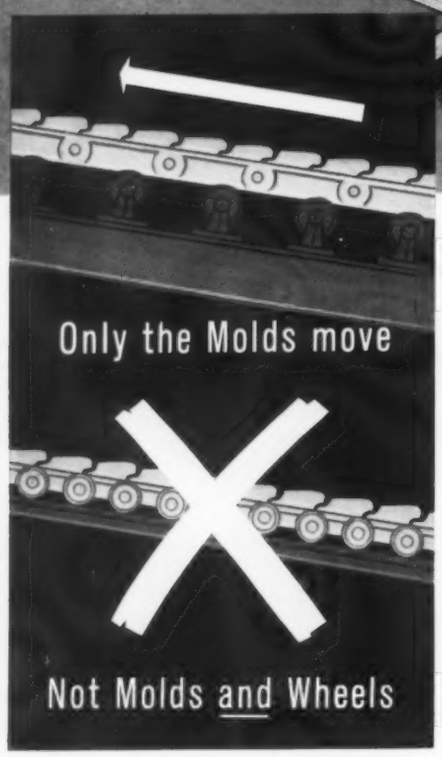
A similar length of pipe was installed, with Style 123 couplings installed every 40 ft. The maximum contraction at any place was only 0.075 in., and the maximum movement at the gasket was about $\frac{1}{32}$ in. In other words, maximum movement of the pipe had been reduced from 0.375 to 0.038 in., and damaging motion to the coating had been reduced by 90 per cent.

Extrapolating the 400 ft of pipe to 4000 ft, the motion in all-welded line could have been at least 3.75 in., while the maximum motion for the coupled pipe would have

BURNERS INCREASE BILLET HEATER CAPACITY

Production capacity of this billet heater at an eastern specialty steel plant was increased by 30 per cent through the addition of North American Manufacturing Co.'s flat flame burners in the convection zone. Three rows of three burners each (see arrows) are suspended in the roof, one of these rows being in the sloping portion of the roof. The flames of these gas-fired burners spread horizontally in all directions, heating the roof refractory so that it can radiate more heat to the load. Since there is no forward velocity to the flames, there is no danger of uneven heating due to flame impingement even though the billets are only 13 in. from the face of the burner tiles.





Let STATIONARY WHEELS Reduce your Pig Casting Costs

Eliminating 80% of the parts of conventional pig casting machines, this simplified design results in sharp reductions of lost production time and maintenance costs. Since the idler wheels are mounted on anti-friction bearings on the stationary part of the frame, not on the molds, they are positioned as far as possible from hot metal.

Capacities for the machine illustrated: from 3 to 50 tons per hour. Sizes: 15 to 125 feet. Other Bailey Pig Machines are made in single and double strand types and in capacities to 250 tons per hour. Both types feature stationary wheel construction.

WILLIAM M. Bailey COMPANY
ENGINEERS
LEADERSHIP THROUGH QUALITY
1221 BANKSVILLE ROAD PITTSBURGH 16, PA.

remained the same −0.038 in.

Laboratory and field tests conducted by Dresser engineers showed that if no touch-up is done after a Style 123 "Stab-Clad" coupling is installed every 40 ft, the bare area of pipeline due to lack of touch-up may be about 0.3 per cent. This means that if the rest of the pipe is only 0.1 per cent bare, the finished pipeline will be 99.6 per cent coated.

Further means of protection against holidays is supplemented to the triple-coating system of the Style 123 by use of armored gaskets. When coupling bolts are fully tightened, the armor bites into the pipe, providing electrical conductivity across the joint. Twenty-year tests in the field and in the lab indicate that conductivity will be entirely adequate with a large factor of safety.

Added protection is afforded by a flexible "S" shaped bond wire, welded to middle ring and followers of the coupling. Made of a soft flexible steel of the same type as the rest of the coupling to avoid use of dissimilar metals, the wire is arc-welded from flange to middle ring to flange. The most important cathodic protection current flow is from the pipe through the armor to the middle ring to the other armor and back to the pipe, but the bond wire provides a path for current flow from the middle ring to the bolts and flanges as well, wiring the whole coupling together as one electrically conductive unit.

A two-in. pipeline, 9000 ft long, was installed using 225 of the new couplings. Factory-coated pipe was used in 40 lengths, and all work was done in weather at an ambient temperature of 35 F.

The pipe used had storage corrosion on the cut-back at ends and was not in the normally ready-to-use condition of mill-coated and wrapped pipe. Nut ends of bolts and occasional damage to outer layer of enamel was not touched up. Wire leads were attached to the pipe about every 200 ft to permit installing protective anodes where needed.

This line was installed two and one half years ago, and is still in perfect condition. Installation time of the line showed labor savings over other joining methods in the ratio of 1 to 3.

This is the new Signode M20-SV

Versatile new strapping station for strip steel coils

This new strapping station accommodates strip steel coils from ⅜″ to 16″ wide and up to 60″ in outside diameter. The operator positions and indexes the coil manually (power optional) and inserts the strap end. All other strapping functions are by push-button. Versatility and speed are combined with economy. Strap feed and take-up are unlimited. There's no reaching across the coil—all operations are immediately in front of the operator. And the strapping is sealed on the top face of the coil, where it is visible, inspectable, clean, and away from conveyor rollers.

The strapping is done by the superbly engineered Signode M20 head that has proved capable of trouble-free performance through millions of cycles in continuous high speed production line use.

There are many more interesting facts about the M20-SV available from Signode. Write now, or ask the Signode man near you.

Can we show you our new 10-minute color motion picture of this machine?

First in steel strapping

SIGNODE
STEEL STRAPPING CO.
2644 North Western Avenue • Chicago 47, Illinois

Offices Coast to Coast. Foreign Subsidiaries and Distributors World-Wide
In Canada: Canadian Steel Strapping Co., Ltd., Montreal • Toronto

THAWING STATION

△ A one-man thawing station, possibly the most "automated" of its type installed to date, enables the Baltimore Gas and Electric Co. to thaw up to 10 cars an hr. The 225-ft-long thawing facility handles five cars at a time.

Thirty-six prefabricated thawing pits are so arranged that any size car, or any combination of sizes in a five-car train, can be thawed effectively without damaging the cars. Each pit radiates heat at the rate of 1.5 million Btu per hr. The arrangement of the pits makes available to each car as much as 6,000,000 Btu per hr.

This thawing station was designed and engineered cooperatively by Hauck Manufacturing Co. and the Baltimore Gas and Electric Co.

Winter stockpiling involved a thawing problem not faced by stations receiving their coal by barge. Because of the cold weather, thawing was required before the cars could be dumped and the coal sent on conveyor belts to the stockpile. The cars had to be unloaded and released in a reasonable length of time if demurrage was to be avoided.

The specially-designed thawing station is operated from three remote control panels. The operator simply pushes buttons to start up the individual thawing pits he wishes to use. In the event of failure of air pressure or of fuel or power supply, shut-off is automatic. This feature, plus remote control, virtually eliminates the injury hazard to operators existing in some non-automatic systems.

The panels from which the pits are individually controlled are installed on a trackside windbreak. The first step in a thawing operation is manually igniting all pilots. The pilots remain in service as long as desired so that the operator will get instantaneous response.

Because of the large number of pits and their control by push-button operation, radiant heat can be provided immediately to key areas regardless of the makeup of the train. Determining which pits are to be used for thawing depends on the size of the cars.

The operator takes his cue from the lead car. This car is properly positioned over the pits to establish a point of reference. After this is done the operator need only observe the position of the cars along the track and start up those pits that are located under areas to be heated.

This flexibility of operation not only speeds thawing and saves fuel but also avoids damage to the hopper cars. Any thawing pit beneath a car section vulnerable to damage by heat is not operated.

Each of the 36 prefabricated pits, rated at 1,500,000 Btu per hr, contains two burners, a pilot and safety equipment. The pits have hinged, split covers that fold back readily during thawing operations. The covers remain closed to protect the pits when not in use. The burners and controls are protected by individual covers.

Use of prefabricated pits can reduce considerably the cost of installation of a thawing station. Prefabricated pits require no underground form work. At the time the pits are installed a railroad tie is removed from each pit location. No other alteration to the track is necessary. When a thawing station is planned in conjunction with new track, ties are omitted where the thawing pits are to be placed.

Continuous Crushing of Hot, Highly-Abrasive Materials

McLANAHAN SINCE 1835

SINTER BREAKER

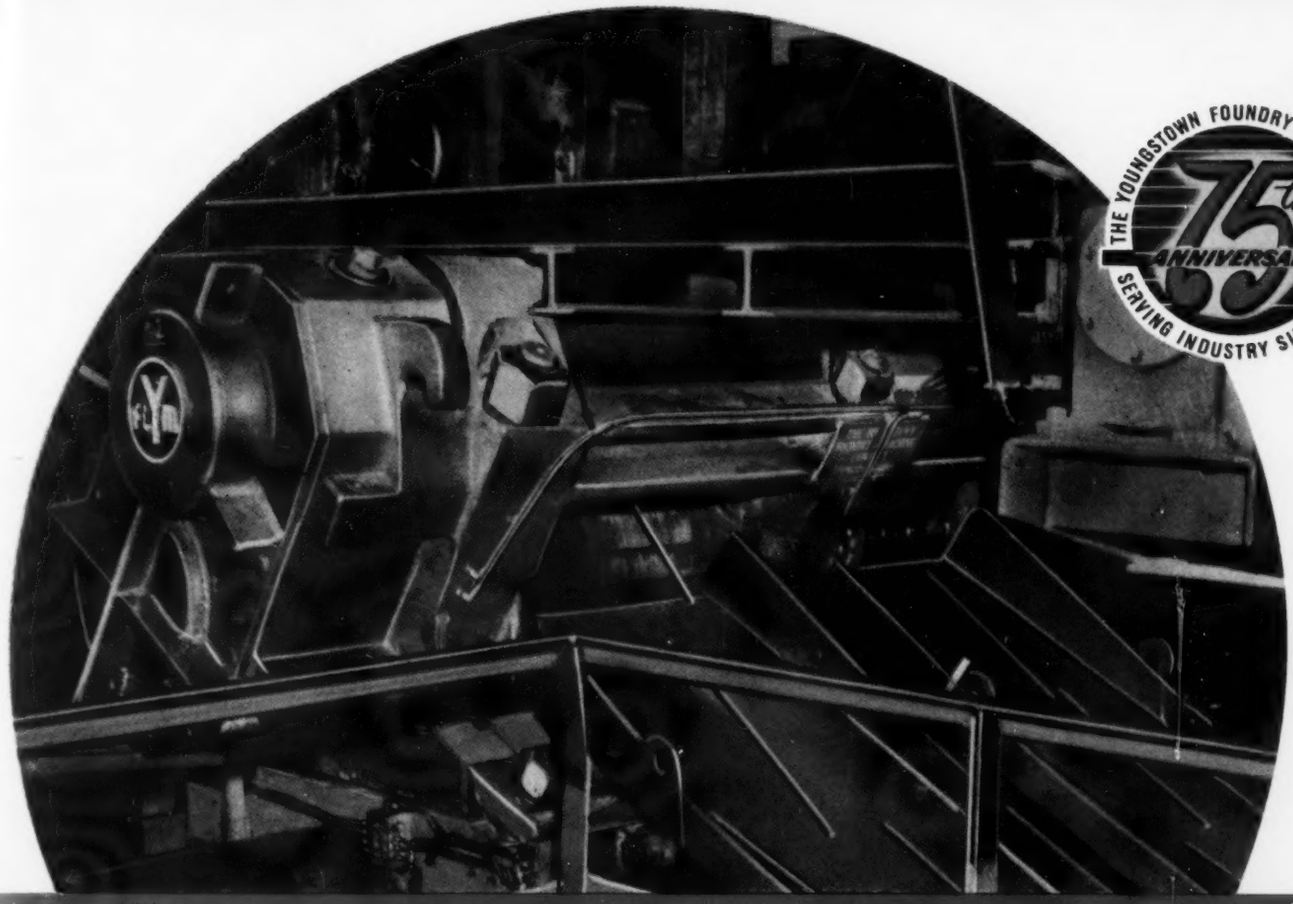
- Water cooled crushing roll, roll shaft and bearings
- Integral 9" hard-surfaced teeth
- Non-plugging, tapered, Ni-hard grate bars

Designed to crush any volume of material that can be discharged to it by the sinter machine, the McLanahan Sinter Breaker is rigid and powerful—constructed for continuous, low-maintenance performance. Standard widths, 72" and 94"—other sizes custom engineered.

Write for details.

McLANAHAN Corporation

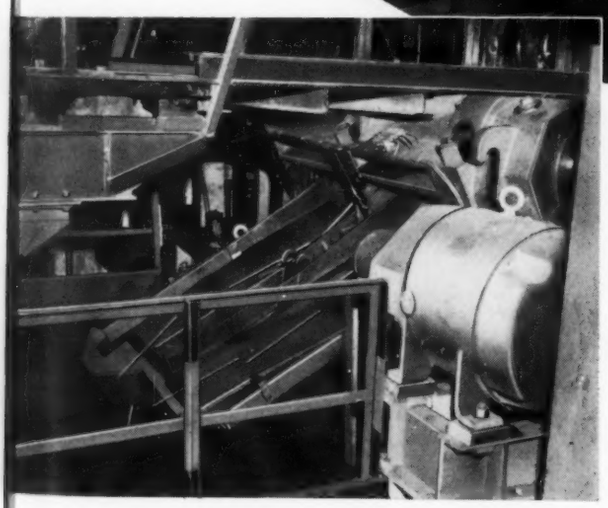
HOLLIDAYSBURG, PENNSYLVANIA



THE YOUNGSTOWN FOUNDRY & MACHINE CO. 75th ANNIVERSARY SERVING INDUSTRY SINCE 1986

"YOUNGSTOWN"

Rotary-Type PLATE SCRAP CHOPPER



Scrap sliding down exit chutes from rotary chopper onto conveyor which discharges into scrap box or railroad car.

Unique Reciprocating Design prolongs knife life... saves downtime

Here's the scrap chopper designed for ruggedness and efficiency... built by "Youngstown" for a leading steel company. It handles side trimmer scrap 3" wide, ⅛" to ½" thick and cuts to 14⅛" constant length at speeds of 45 to 180 fpm. This rotary type scrap chopper is also built for ¾" and 1" thick plate; it can be built integrally with a side trimmer for a new line or application.

The arbor and housing assembly is designed as a separate unit mounted on a motor driven reciprocating carriage. Each arbor is equipped with four 30" long knives, with the knives so spaced that only one side is cutting at a time. This feature, along with the reciprocating action, insures longer time between knife dressings.

This design provides a spare housing and arbor assembly so that knives can be changed or adjusted on the floor, saving valuable mill time while changing knives. Housing and arbor assembly change time is held to a minimum through fast disconnect from drive and reciprocating carriage. Write for complete information.

The Youngstown Foundry & Machine Co. Youngstown 1, Ohio

AiR MOVEMENT

NOW available for those few applications that demand it

Our ruggedly built crane cab air conditioner is now available with an optional grill that increases air velocity. While this option is not needed except for highest radiant heat locations, it is nice to know that Lintern thinks of everything.

Should you wish to order this grill, ask your Larco representative for "option B".

Other Lintern products backed by 32 years of know-how include replacement crane cabs, traction sanders for overhead cranes, glowlites, and signal lights.

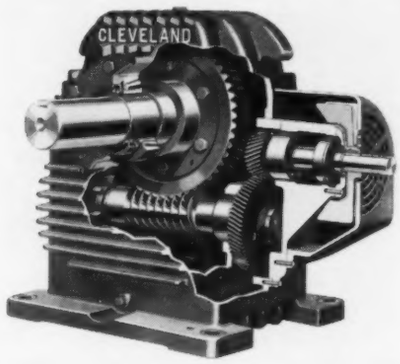
More **Lintern** *Aire Rectifiers cool more cabs and pulpits than any other make.*

DISTRIBUTED BY LARCO, INC., Painesville, Ohio

SPEED REDUCERS

△ Fan-cooled helical worm gear speed reducers are available from Cleveland Worm & Gear Division, Eaton Manufacturing Co., in ratios extending approximately from 34 : 1 to 394 : 1. The reducers come in seven sizes, ranging from 4- to 12-in. center distances. Ratings are fractional to 58.5 hp.

Helical primary gears are cut from high hardness steel. In the



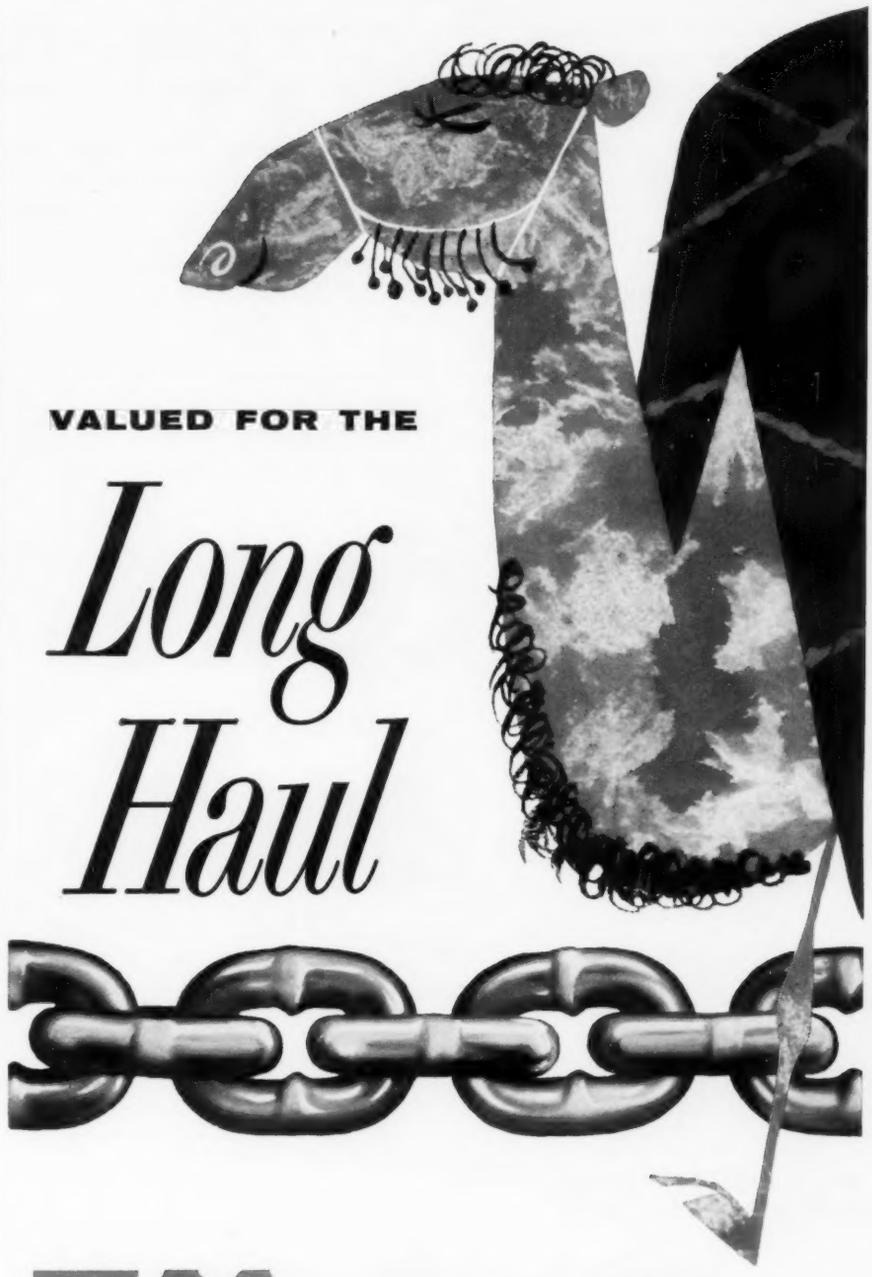
secondary reduction, worms are machined from medium carbon steel hardened by the "Flamatic" process, which results in a high degree of hardness to well below the root diameter, while maintaining the advantage of a core of medium strength. For increased wear and fatigue resistance, the worm gears are cut from bronze of a high tin-copper content and are bolted or mechanically keyed to cast iron hubs.

On larger sizes, both primary and secondary gear trains share a common housing, while separate housings are used on four in. through six-in. sizes. In all sizes, both gear reductions share a common oil bath. Shafts are supported by ball and tapered roller bearings sized for heavy radial and thrust load capacity.

SAFETY CAGE

△ The first "safety cage" exported for the maintenance of ladles in steel mills has been shipped to West Germany by the Sticker Industrial Supply Corp. The equipment has been used in this country for several years.

The "safety cage" is an insulated vessel, provided with ventilated ladders and other accessories which permit it to be lowered into the hottest ladles immediately after the pouring of the molten steel.



VALUED FOR THE

Long Haul

TM alloy slings

"Stamina for the long haul!" That's the frequent comment on the performance of TM Alloy Sling Chains in steel mills, foundries, forge shops, mines and countless other industries.

Bulletin 14A—packed with facts and specifications—gives you many reasons why TM Alloy Chain is valued by so many. Call your industrial distributor, steel warehouse, hardware wholesaler, or write today for your copy.

Taylor Made CHAIN SINCE 1873

Prompt repairs on alloy slings in both plants.

S. G. TAYLOR CHAIN CO., Inc.
Plants: Hammond, Indiana
3505 Smallman St., Pittsburgh, Pa.

Workmen enter it instantly and perform their work on its bottom in complete comfort and safety.

Heretofore, the repair crew has been delayed for many hours from entering the cooled off ladle and replacing the refractory nozzle in its bottom.

VERTICAL WIRE BLOCKS

Δ Incorporating every known design feature, construction advancement and operating convenience for drawing wire faster and at lowest cost per bundle, a completely re-engineered line of vertical wire blocks is announced by Morgan Construction Co.

Produced in both single and double deck arrangements, the new "Mordraw" machines are offered in three basic models, spanning a range of block sizes from 16 through 42 in. Ample power is assured by motor ratings up to 250 hp, maximum, and drives can be arranged for either the die side or right-hand side of any machine.

Outstanding new feature of "Mordraw" blocks is their remarkably low draft line 32 in. on a majority of models, 34 in. on largest block produced. This eliminates effectively all problems and expense attendant with construction of special platforms or pits at the installation site. Also, this development substantially reduces fatigue and improves working ease for the wire drawer. Other benefits provided by the new design include ability to handle heavy bundles and an exceptionally high cooling rate. Optional air only or air-and-water systems attain new levels of cooling efficiency—taking heat out fast before wire is affected, making it practicable to run out really heavy bundles, safely and speedily.

Double-deck, individually-adjustable die boxes are located on the same machine bracket, eliminating need for crossing rod line in threading upper deck. Die stand on double-deck models can be raised or lowered to provide single or double draft operation. Blocks are cast alloy iron, hardened at the draft line to a Brinell in excess of 500. Blocks can be supplied with special hard-faced, long-wearing alloy as an extra-cost option. Block changes are made easily and quickly through use of tapered fits throughout.

Extreme compactness of the new "Mordraw" vertical wire blocks conserves floor space making it possible to install more machines in a given production area. In addition to the low draft line, ease of operation is further aided by conveniently located, logically grouped operating and safety controls. Notably quieter operation has been achieved through liberal use of anti-friction bearings and worm gear drive.

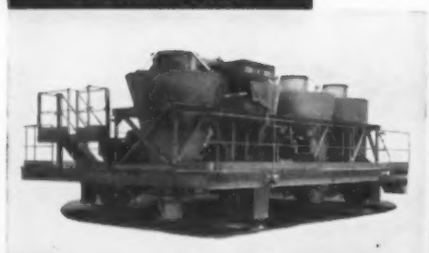
Standard accessories, furnished with each machine, include water-cooled die holders; grip for starting wire; tilting type snarl stop and collapsing stripper for removing bundles. A complete range of optional features and equipment is also available to increase productivity and individualize machines to each operation. Options include: interchangeable blocks, air only cooling, air-and-water cooling, riding strippers in collapsible or rigid types, d-c variable drive, a-c multiple or single-speed drive, lubricant tank and pump for circulating wet lubricant to die, speed indicators and predetermining counters.

QUENCHER LOCOMOTIVE

DOOR MACHINE

COKE
ON THE
MOVE

Operating economy and long life, again, are major advantages of Atlas equipment for highly specialized coke-producing service. Specially designed and ruggedly built to your exacting requirements.


COAL LARRY

COKE QUENCHING CAR

ATLAS CAR & MFG. COMPANY

Since 1896, Engineers-Builders of Ore Transfers...Scale Cars...Coke Quenchers...Coal Larries...Door Machines...Safety-Type Transfers ...Storage Battery Locomotives.

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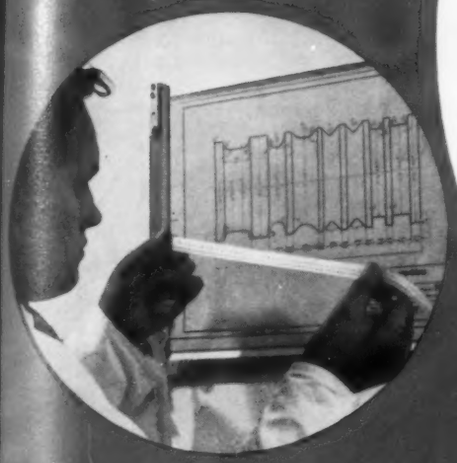
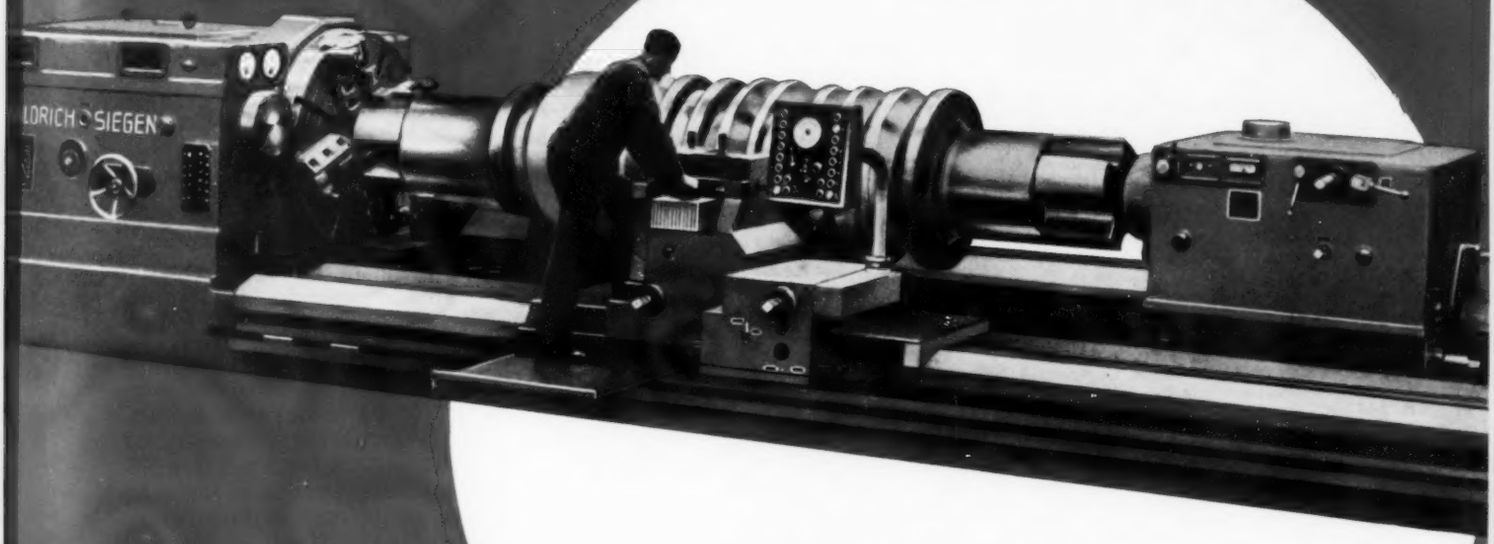


NEW DEVELOPMENT
by WALDRICH SIEGEN

Outstanding West German Heavy Machine Tool Manufacturer



NUMERICALLY CONTROLLED ROLL GROOVING LATHE

No need for specially trained operators
No templates
Longer service life of rolls, as our positioning system computes automatically the most favorable position of grooves.

WALDRICH SIEGEN

H. A. WALDRICH G. M. B. H. SIEGEN · GERMANY

AMERICAN WALDRICH MFG. CORP. • 1232 Penn Avenue, Pittsburgh 22, Pa.

NEWS FROM

LOMA

After an initial "breaking-in" period, this large LOMA slab casting and sawing installation is now in full production at the aluminum sheet rolling mill of the Quaker State Metals Company, Lancaster, Pa., a division of Howe Sound Company. Capable of producing six 7½ in. x 52 in. x 144 in. aluminum alloy slabs simultaneously, the LOMA semi-continuous casting machine turns out all the ingots required for the processing of sheet, strip and coil. From a quality point of view these continuously cast slabs are greatly superior to those formerly cast in conventional book molds, particularly since one of the methods by which the grain size of the cast material can be controlled is by regulating the casting speed.

For subdividing and trimming the 12 ft. long sheet ingots, Quaker State has also installed a LOMA high-speed circular saw capable of cutting through a 12 in. x 52 in. aluminum alloy section in about one minute. The sawing machine is of the overhead sliding carriage design and employs a 48 in. diameter blade cutting at a speed of 6000 ft. per min. The sawing installation includes a slab charging conveyor, an automatic length stop, a slab discharge conveyor and a chip removal unit. This fully mechanized stock handling equipment combined with the extremely fast feed movement of the saw allows a single operator to run the entire installation at a very high production rate.

LOMA

MACHINE MFG. CO., INC.

114 East 32nd Street

New York 16, N. Y.

STEEL STRAPPING UNITS

△ A new series of steel strapping machines, all incorporating a basic strapping mechanism described as the most compact, low cost yet developed, has been announced by Acme Steel Co.

The series, called F7, has the new strapping mechanism in side or top mounted position so that installations can be custom adapted to fit individual production line requirements.

In the most simple system an F7 has a basic strapping mechanism side-mounted on a conveyor-height stand, and is equipped with controls for semi-automatic operation. More sophisticated production line models of the F7 include full package-circling tracks and controls for fully automatic strapping.

The new basic strapping mechanism used in all F7 machines is a self-contained, completely air powered and electrically controlled unit weighing about 75 lb. It can be mounted on 12-in. centers in multi-strap arrangements. Maximum length of strap feed and take-up is unlimited.

The mechanism itself contains pneumatic machinery for strap feed, take-up, cutting and sealing plus an integral magazine for 100 metal seals. Electrical controls are mounted in a separate console. Larger capacity magazines, package compression cylinders, reciprocating tracks for feeding strap through double-face pallets and other special equipment is available for most F7 models.

Air supply requirement varies from 60 to 90 psi depending on tension needed. The control unit operates on standard 110-volt, 60-cycle current, with a power consumption of 15 amp. Simplified design of both electrical and pneumatic power circuits allows repair work to be done by regular maintenance personnel.

Because of its lightweight and hand portability, the basic strapping mechanism can be interchanged between different F7 machines. Use of one mechanism as a standby unit allows in-service mechanisms to be rotated for preventative maintenance or repair in less than five min with little or no disruption of production.

The strapping mechanism handles

B·I·F FIRST . . . IN MEASUREMENT AND CONTROL OF MATERIALS FLOW

Do blending errors and equipment failures reduce your profits through shutdowns and replacements? If payloads were dollars, would you settle for accuracy based on intermittent feeding? B-I-F's performance-proved coal blending system weighs and controls every pound of coal, has unlimited capacity, and maintains an accurate preset blend.

Free Facts

Continuous feeding and blending saves material, reduces cost, improves quality . . . results in bigger processing profits.
Write for free — Facts today!

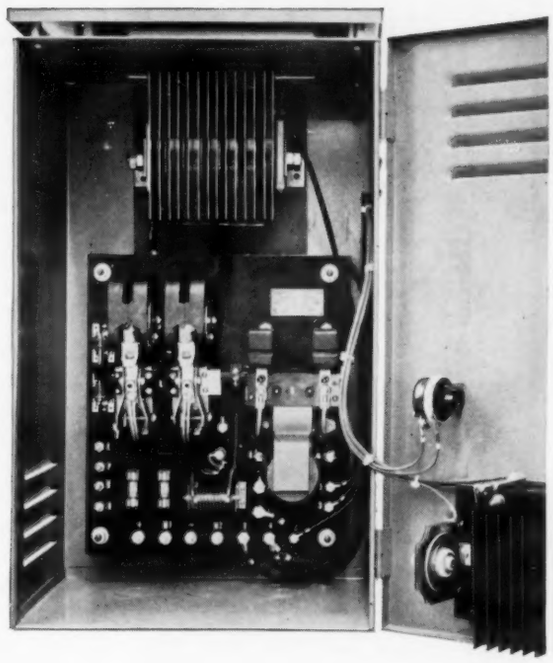
B·I·F Industries

BUILDERS-PROVIDENCE • PROPORTIONEERS • OMEGA
547 HARRIS AVENUE, PROVIDENCE 1, RHODE ISLAND

EUCLID

LIFTING MAGNET CONTROLLERS PROVIDE 3-WAY RELEASE

Euclid Bulletin 4290 automatic discharge type magnet controller is the only one on the market today that will assure fast and clean release of full load, accurate release of partial load and precise control of dribbling. It can be used with all types and makes of lifting magnets in any industrial application.



EX-26

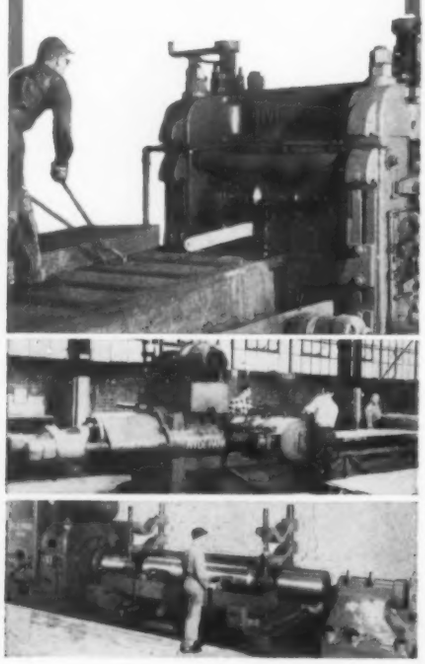
CUSTOM ENGINEERING IS OUR BUSINESS

We specialize in designing the control system best suited to your individual needs. Our services are yours for the asking. WHAT'S YOUR PROBLEM?

Ask for Bulletin 4290

The EUCLID Electric & Mfg. Co.
Dept. A • MADISON • OHIO

Hyde Park
ROLLING MILL EQUIPMENT



Hyde Park Engineers are always ready to co-operate with you in selecting and applying the rolling mill equipment best suited to your operation.

Bar Mills • Merchant Mills
Sheet and Strip Mills
Stretcher Levellers
Roller Tables • Pinion Stands
Sheet Mill Shears
Roll Lathes • Reduction Drives
Special Machinery • Machine Work

Hyde Park
FOUNDRY AND MACHINE CO.
HYDE PARK
Westmoreland County, Penna.

Rolls
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strap widths of 3/8, 1/2, 5/8 or 3/4 in. Gage capacities with any width strap head are 0.015, 0.018, 0.020 and 0.023 in.

The F7 will operate on a minimum package face of four in., and have capability for receiving packages from either right or left-moving conveyor systems.

BACK-UP ALARM

△ A new back-up alarm, primarily for heavy duty service under adverse conditions, has been designed by Femco, Inc.

The device automatically sounds an intermittent warning signal whenever equipment controls are in reverse. The pitch of the signal is well above the level of normal background noise, and volume is adjustable.

Essentially, the unit consists of a heavy cast aluminum loudspeaker with integral housing containing a transistorized tone oscillator which operates from any 6, 12 or 24-volt d-c power source. The whole assembly is weatherproof.

Although designed originally for mill equipment, the back-up alarm is applicable for use on construction and mining equipment, trucks and other vehicles.

DESCALER

△ A blast descaling machine, capable of processing an average of 120 tons per hour of continuous steel coils, has been in operation at Empire-Reeves Steel Corp.

Completely automatic with a central push-button control panel, the 60-ft-long machine prepares hot-rolled carbon and silicon strip for cold rolling. The strip is used in automotive, electrical and galvanizing applications. Designed and built by Pangborn Corp., the installation will accommodate any strip between 24 and 50 in. wide.

Composed of three integral blast cabinets to simplify abrasive handling, the unit hurls 660 tons of abrasive per hour of blasting. Twelve Rotoblast wheels (totaling 900 hp) cover both sides of the strip simultaneously—six blasting downward, six upward. Each of the three cabinets contains a separate abrasive cleaning and recycling system. This includes two double-capacity

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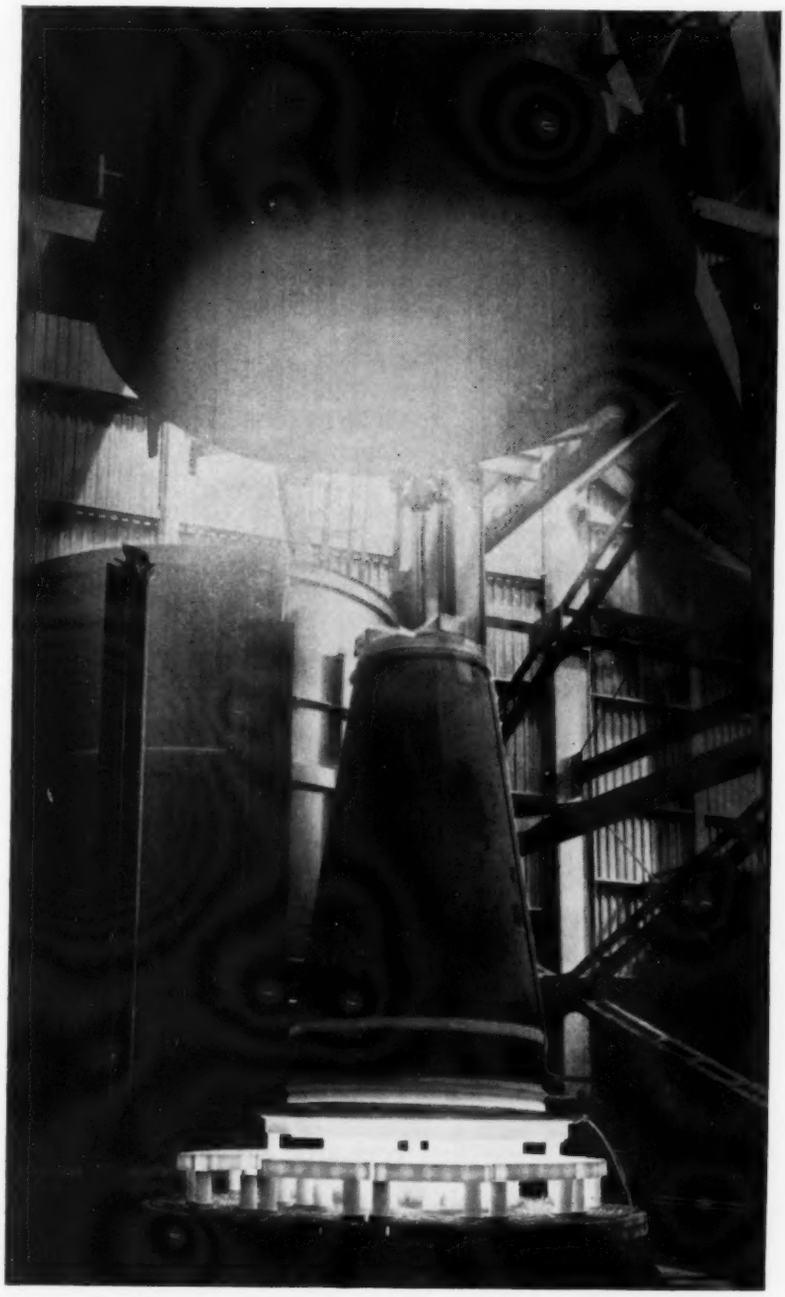

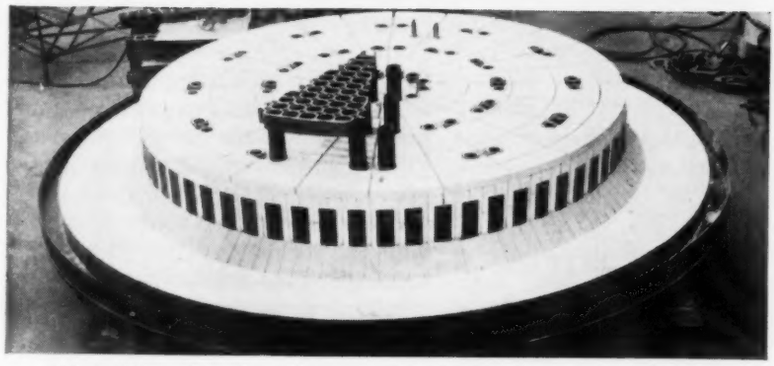

Supertherm hearth grid segment during furnace construction.

In a brazing furnace for the thrust chambers of rocket engines at Rocketdyne Division of North American Aviation, Inc., Canoga Park, Cal., a Supertherm furnace hearth grid assembly is operating at a temperature of 2300° F. The grid in a furnace built by the General Electric Company's Industrial Heating Department at Shelbyville, Ind., supports the engine parts during a brazing cycle of from five to eight hours with a maximum temperature of 2300° F. At this extreme temperature and under severe conditions of thermal fatigue created by the brazing cycle, *the Supertherm grid has performed successfully over one year.*

Supertherm is Electro-Alloys' new alloy for the 1800 to 2300 degree fahrenheit range. The composition of Supertherm is 26% chromium, 35% nickel, and is strengthened and stabilized with cobalt and tungsten. For technical information about the composition, physical and high temperature properties of Supertherm, fill out and return the coupon or contact your local Electro-Alloys representative.

*Supertherm is a patented alloy.

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elevators and two air-wash separators, feeding a single abrasive storage bin which supplies four Rotoblasts. Each pair of Rotoblasts (upper and lower) is adjustable for optimum coverage of various strip widths. Each may be removed for maintenance without stopping the machine or requiring a man to enter the cabinet. These and other features provide a completely fail-safe operation and allow a continuous flow of strip through the unit.

Abrasive consumption averages approximately 25 per cent less than was anticipated. S-170 Rotoblast steel shot is used exclusively. Replenishment of the abrasive supply in each cabinet is accomplished automatically by a bin level sensing system.

METER MARKING DEVICE

△ Substantial savings in service time and costs have been effected, and recording reliability has been improved, by a new ink-cartridge meter marking device now undergoing field tests by the Alan Wood Steel Co., and in other industrial plants employing up to several thousand meters for recording and control purposes.

At Alan Wood, three test installations of the new device have been operating satisfactorily, with minimum servicing, since the spring of 1960. Two of the installations are subjected to high temperatures, one of them being on a panel board in front of an open hearth furnace where dust as well as heat is a hazard to meter marking performance.

Developed by Esterbrook Pen Co., the new marking device substitutes a capillary system drawing ink from a disposable cartridge, for the conventional manually-filled, open-bucket type system. Because the cartridge contains sufficient ink for up to several months of operation, the one, two or three fillings a day which may be required by the open-bucket systems are eliminated.

Failure to mark due to clogging of the ink flow is also eliminated, since the dust, dirt and moisture that cause clogging cannot get into the system. The ink cartridge is sealed until punctured by the capillary tube when inserted for use. The transparent plastic cartridge assures visibility of the ink supply at all times. Replacement of an exhausted cartridge takes only a few minutes.

The meter marking device is readily adaptable to all existing-type recorders — circular, strip, miniature and plotter.

D-C MOTOR FRAME

△ D-c motors and generators (Type SK) frame diameter 190, with reduced inertia for faster response and increased mechanical stability for lower vibration, are now available from the Westinghouse Electric Corp. Typical machine ratings are 500 hp at 850-rpm 240-volts drip-proof enclosure and 800 hp at 1150-rpm 600-volts force-ventilated for heavy industrial applications. Corresponding generator ratings offered with drip-proof construction are 480 kw at 850 rpm for 250-volt d-c power supply.

The ribbed construction at the base of the frame gives self-supporting prealined rigidity. Moreover, by the use of brackets and ball bearings, the weight and the required floor space are reduced. In addition, improved insulation and commutation, lengthened armature and decreased armature diameter result in reduced inertia to give the necessary response for automated production lines.

The higher commutating ability, improved speed of response, and better regulation are the new performance standards for these sizes and are supplemented with compensating field windings as required.

TORQUE-ARM REDUCER

△ Latest addition to the line of torque-arm speed reducers by Dodge Manufacturing Corp. is a size 17 single reduction unit with 5 : 1 gear ratio capable of transmitting 50 per cent more horsepower at output speeds up to 400 rpm.

The new shaft-mounted reducer develops greater torque than any other single reduction unit in the line, and can accommodate 60-hp motors in the top range of ouptut speeds based on Class 1 AGMA ratings. This new reducer may be applied to equipment operating in the speed range above that of Dodge 15 : 1 and 25 : 1 double reduction reducers and in the horsepower range exceeding that of the No. 16 reducer, which is designed to accommodate motors up to 40 hp.

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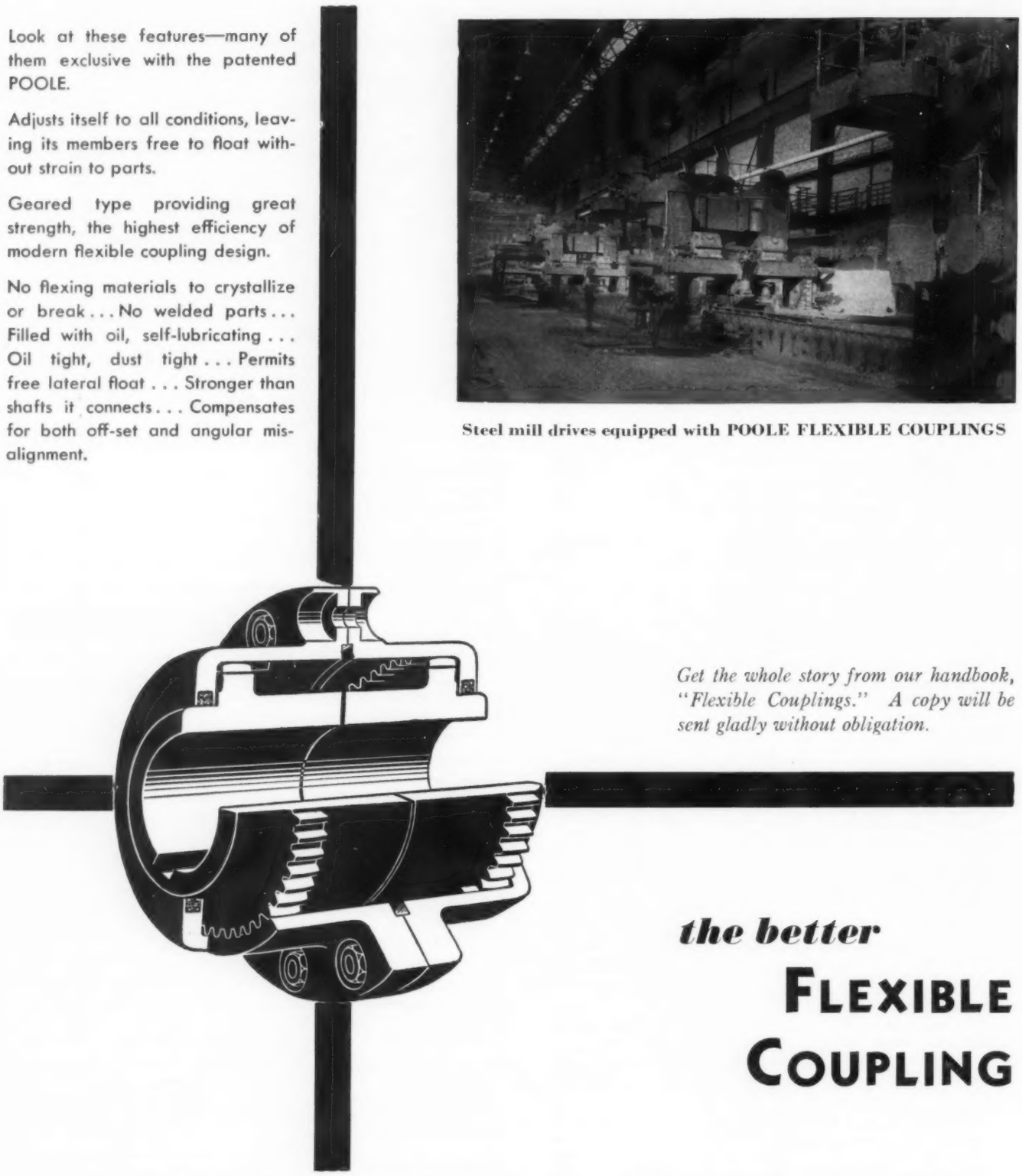

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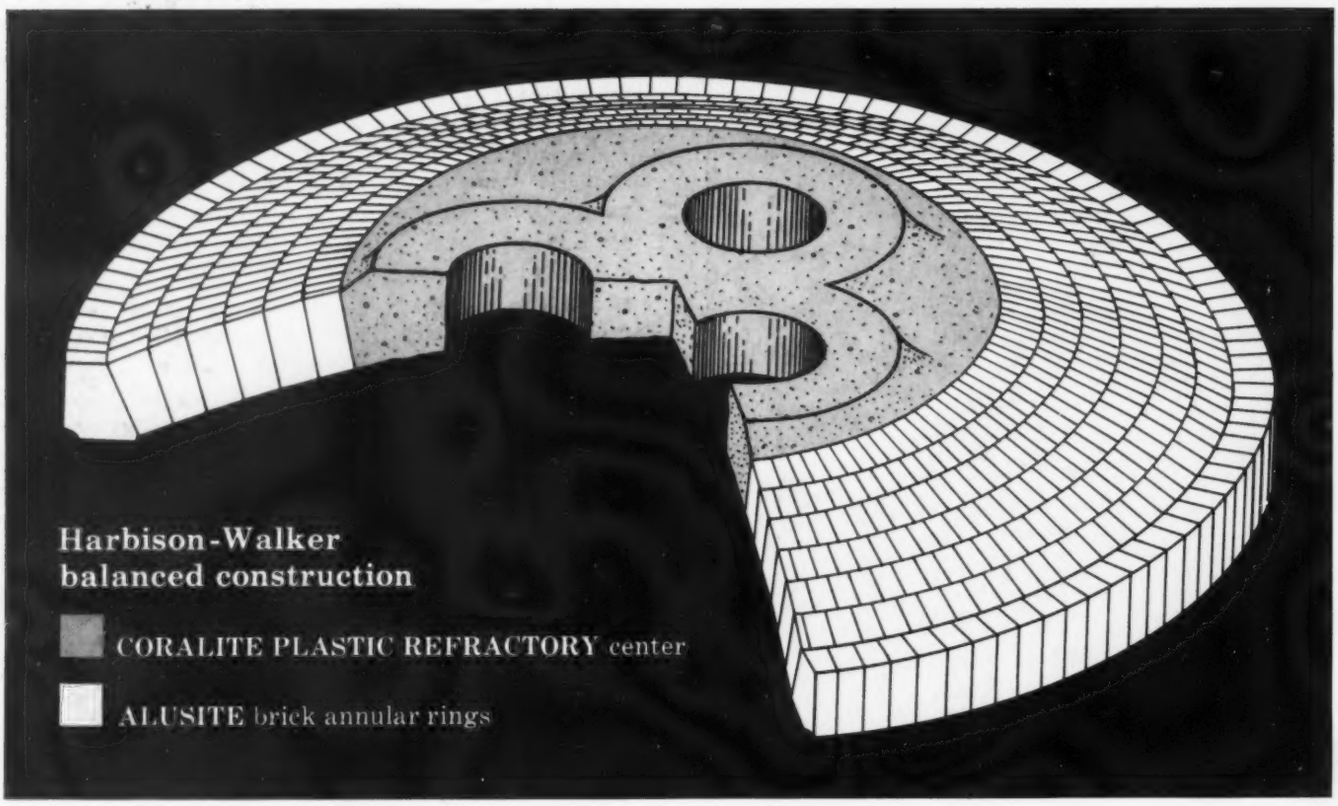

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